1968

Observations on the decline of the Rock Creek Montana population of bighorn sheep

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The University of Montana

OBSERVATIONS ON THE DECLINE OF THE ROCK CREEK,

MONTANA, POPULATION OF BIGHORN SHEEP

by

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B.A., University of California at Berkeley, 1966

Presented in partial fulfillment of the requirements for the degree of

Master of Science in Wildlife Management

UNIVERSITY OF MONTANA

1968

Approved by:

Chairman, Board of Examiners

Dean, Graduate School

OCT 1 1 1968

Date

ACKNOWLEDGMENTS

It is my pleasure to acknowledge the cooperation given to me by several of the many people who have shown an interest in the bighorn sheep.

I am grateful to the residents of the upper Rock Creek Valley, particularly Bob Neal and his family who have been such wonderful companions during the past two years and who have provided invaluable assistance whenever called upon.

Mr. Joe Mazzoni, refuge manager of the National Bison Range, has made available his facilities and records throughout the study.

Drs. J. Brogger, W. Hawkins, and B. Hubbell have provided assistance in the veterinary aspects of the study.

To Hoke Grotbo and the personnel of the Philipsburg ranger station, Deer Lodge National Forest, a special note of thanks for their interest and support.

To my partners and field companions, fellow students Mike Aderhold and Al Cooperrider, I am grateful for the privilege of sharing their enthusiasm and companionship, and for aid in the collection of data throughout the field work.

Mr. Ken Greer of the Wildlife Conservation Laboratory, Montana Fish and Game Department, has made available his time and facilities which were both employed so extensively in the analyses of the rumen samples.

Dr. George Blake, Dr. Lee Eddleman, and Professor Melvin S. Morris were always available for advice in the design and conduct of the range studies.

The financial support which made this study possible was provided by the Montana Cooperative Wildlife Research Unit,[1/] the School of Forestry of the University of Montana, the Montana Department of Fish and Game, the American Museum of Natural History and the National Wildlife Federation.

I am particularly grateful to Dr. Richard D. Taber, my advisor and committee chairman, who has guided the course of this study since its inception. His counsel and patience while I was grappling with the problems of the study have resulted in a genuine and lasting educational experience.

I am grateful to the other members of my committee, Dr. John Harris, Mr. Reuel Janson, Dr. W. Leslie Pengelly, and Dr. P. L. Wright for their continuing support and advice.

Dr. John J. Craighead and my wife Mary Anne gave the suggestions and time during the course of preparing the manuscript which made the completion of this study possible.

[1/] U. S. Fish and Wildlife Service, Montana State Department of Fish and Game, University of Montana, and The Wildlife Management Institute cooperating.

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INTRODUCTION

Buechner (1960:13), using Cowan's (1940) taxonomic revision of native North American sheep, reviews the status of the various sheep populations in the continental United States and the problems attendant to insuring healthy numbers of sheep for the future.

Although the decline of bighorn sheep from over 1.5 million to about 18,000 has been well chronicled (Buechner, 1960:73-74), the precise nature of the bighorn's intolerance of environmental alteration and the mechanism of response at the individual and population levels have not been clarified. The apparent inconsistency of theories on the causes of the decline and range restriction of native sheep, and the lack of response of bighorn sheep populations to management, primarily in the form of protection, emphasize the rudimentary state of present knowledge.

The precarious status of sheep populations obviously demands a rapid increase in the accumulation of biological data and its application in effective conservation measures.

The works of Honess and Frost (1942) in Wyoming, Couey (1950) in Montana, Smith (1954) in Idaho, Moser (1962) in Colorado (Rocky Mountain bighorn sheep, *Ovis canadensis canadensis*); Jones (1950), Jones, *et al*. (1957), and McCullough and Schneegas (1966) in California (California bighorn sheep, *Ovis canadensis californiana*); Russo (1956) in Arizona (Mexican bighorn sheep, *Ovis canadensis mexicana*); Murie (1944) in Alaska (Dall sheep, *Ovis d. dalli*); Welles and Welles (1961) in California and Hansen (1967) in Nevada (desert bighorn sheep, Ovis canadensis nelsoni); describe, in general, the sheep populations residing in geopolitical regions.

Although custodial agencies responsible for management of local bighorn populations have been obliged to devote much of their time and energies to the more "salable" big game species which provide the bulk of recreational hunting license sales, several pioneering studies among those noted above have been promoted by state fish and game departments. Primarily, local agencies have determined the numbers and distribution of bighorn sheep and the possible factors limiting sheep numbers such as: the lungworm-pneumonia complex as reviewed by Forrester and Senger (1964) and questioned by Howe (1966); other diseases and parasites (Becklund and Senger, 1967); forage competition reviewed by Buechner (1960) and updated regionally by Jones (1963) in Alaska, Schallenberger (1966) and Constans (1967) in Montana, and Blood (1959), Sugden (1961), and Flook (1964) in Canada; and predation reviewed by Blaisdell (1961) and Hornocker (1967) (cougars), Elliot (1961) (bobcats), Jantzen (1961) (eagles) and Smith (1954), Russo (1956), Buechner (1960), and Moser (1962) for a general treatment. Production and maintenance of harvestable numbers of trophy bighorn sheep has been a continuing goal of management-oriented agencies. Results of several programs have been discussed by Swank (1958), Buechner (1960), and Hansen (1965). In general, the above studies have been either general surveys, designed for immediate application in management programs, or investigations of a limited problem in a complex ecological situation.

Now, ecological studies of small, endemic populations are being undertaken, particularly under the aegis of university support and direction. Such aspects of bighorn sheep biology as behavior (Blood, 1963; Geist, 1966; 1967), milk composition (Baker, et al., 1967); Chen, et al., 1965), environmental factors (Bandy, 1966), nutrition (Anon., 1957), metabolism (Bradley, 1964), and growth (Cherniavsky, 1962; Forrester and Hoffman, 1963) are being investigated. At present several studies are being conducted to clarify areas of bighorn biology such as breeding and productivity in response to environmental variation (Streeter, 1967) and bighorn sheep physiology (Stelfox, pers. comm.). However, intensive studies of microclimatic influence, the interspecific transmissibility of disease and parasites, and the dynamics of populations altered in structure from those of pristine times have yet to be undertaken. Data from control herds inhabiting well-investigated ecosystems, as suggested by Couey (1950), have yet to be made available for use as standards for comparison. There still remains a good deal of intensive work on sheep biology to be done.

The present study focuses on the Rock Creek, Montana, bighorn sheep. This herd has displayed a dramatic oscillation in numbers. Most recently there has been a steep population decline (Pengelly, pers. comm.). We are attempting in this study to determine its cause.

In light of the decline of the bighorn sheep of Rock Creek, the rapidly changing land use patterns at Rock Creek, and the increasing recreational demands on the wildlife resources of the area, the approach of this first study was broad and emphasized ecosystem inventory. It is important that application of the results of this study can begin while in-depth research continues.

Field work, employing two graduate students, began in December, 1966, and terminated in April, 1968.

Objectives

1) To determine the daily and seasonal movements of the bighorn sheep and mule deer herd on the study site, and to describe the distributional patterns and movements in terms of microclimates and habitat preferences; in particular, to delimit the sheep winter range and the key areas for deer and sheep on the winter range.

2) To determine the numbers and types of domestic and wild animals, resident and migrant, on the bighorn sheep winter range.

3) To study: a) the floral composition and the distribution of plant species of the key areas, b) the total forage production of the winter range, c) the amount of forage being used by each class of animal, d) the present condition and trend of the range resource, and e) the nutritive quality of the forage.

4) To study the food habits of the bighorn sheep, mule deer, and domestic livestock, and to determine by quantitative analyses of rumen samples, feeding-site observations, and behavioral patterns the degree of competition for forage among the major ungulates inhabiting the winter range.

5) To assess the impact of current and past land uses on the habitat and relate this to the populations of animals which have occupied the winter range.

6) To monitor parameters of growth and condition of the sheep and mule deer during their occupancy of the winter range.

7) To study the other factors which might limit the bighorn population, such as predation, disease, poaching, disturbance by humans, and alterations of behavior related to the small bighorn sheep population.

PART I: DESCRIPTION OF THE STUDY AREA AND ITS HISTORY OF LAND USE

Rock Creek drains a considerable portion of Granite County in west-central Montana and joins the Clark Fork of the Columbia River 22 miles upstream (east) from Missoula, Montana. About 35 miles above the mouth of Rock Creek, from its confluence with the Clark Fork, cliffs rise 500-1000 feet from the Rock Creek Valley and grade into rolling south-facing, grassy slopes dissected by timbered draws and ridges (Fig. 1). This is the site of a big game winter range harboring an isolated, endemic population of the Rocky Mountain race of bighorn sheep (*Ovis canadensis canadensis*). Other large native mammals found in the area include moose (*Alces alces*), wapiti (*Cervus canadensis*), white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), mountain goat (*Oreamnos americanus*), black bear (*Ursus americanus*), coyote (*Canis latrans*), mountain lion (*Felis concolor*), and bobcat (*Lynx rufus*). Prior to the white man the area supported populations of bison (*Bison bison*), grizzly bear (*Ursus arctos horribilis*), and timber wolf (*Canis lupus*). The fauna includes an additional 32 mammals as well as 61 bird species (Aderhold, MS).

The winter range has a long axis of seven linear miles lying in a northwest-southeast direction and is one mile wide. The map location is T7N-R16W, Montana Principal Meridian.

The study area encompasses this winter range and is a palouse grassland interspersed with montane coniferous forest at about 5000 feet elevation. The flora is dominated by bunchgrasses and Douglas fir.

The parent materials of the soils identified on the Rock Creek winter range consist of sedimentary and metamorphic rocks deposited about one billion years ago and constituting a portion of the extensive Belt Series found throughout much of western Montana (Aderhold, MS). About 80% of the winter range is underlain by the Ravalli formation of grey-pink argillaceous quartzite and dark blue-green shale. These rocks are typically found in slides and talus of such areas as Windlass Gulch. A more recent Belt formation known as the Helena Limestone occurs adjacent to Rock Creek and forms the cliffs and spire-like "hoodoos" which lead up to the grassy slopes of the winter range. These ochre rocks are extensively stained and are primarily composed of quartz, calcareous argillites, and impure limestone. Eroded Belt materials were deposited during the Tertiary and were metamorphosed into the abundant conglomerate found throughout the limestone cliffs. Alluvial deposits of the above materials form most of the floor of the Rock Creek Valley, and the alluvial fans at the mouths of the side drainages.

The soils of the study area, described in detail in a later section, are shallow, silty to gravelly loams, prone to colluvial movement in steep, exposed sites. Although the grassland soils such as the Donald-Marcetta-Cheadle Association have a dark grassland surface horizon, they were at one time forest soils and have grainy, leached horizons of aluminum-silicates. The grassland formation may, therefore, be the result of fires and an increasingly xeric climate. The shallow soils of the winter range, particularly the Cheadle series, are extremely susceptible to drought because of their shallowness and

Fig. 2 Rock Creek, Montana, and vicinity.

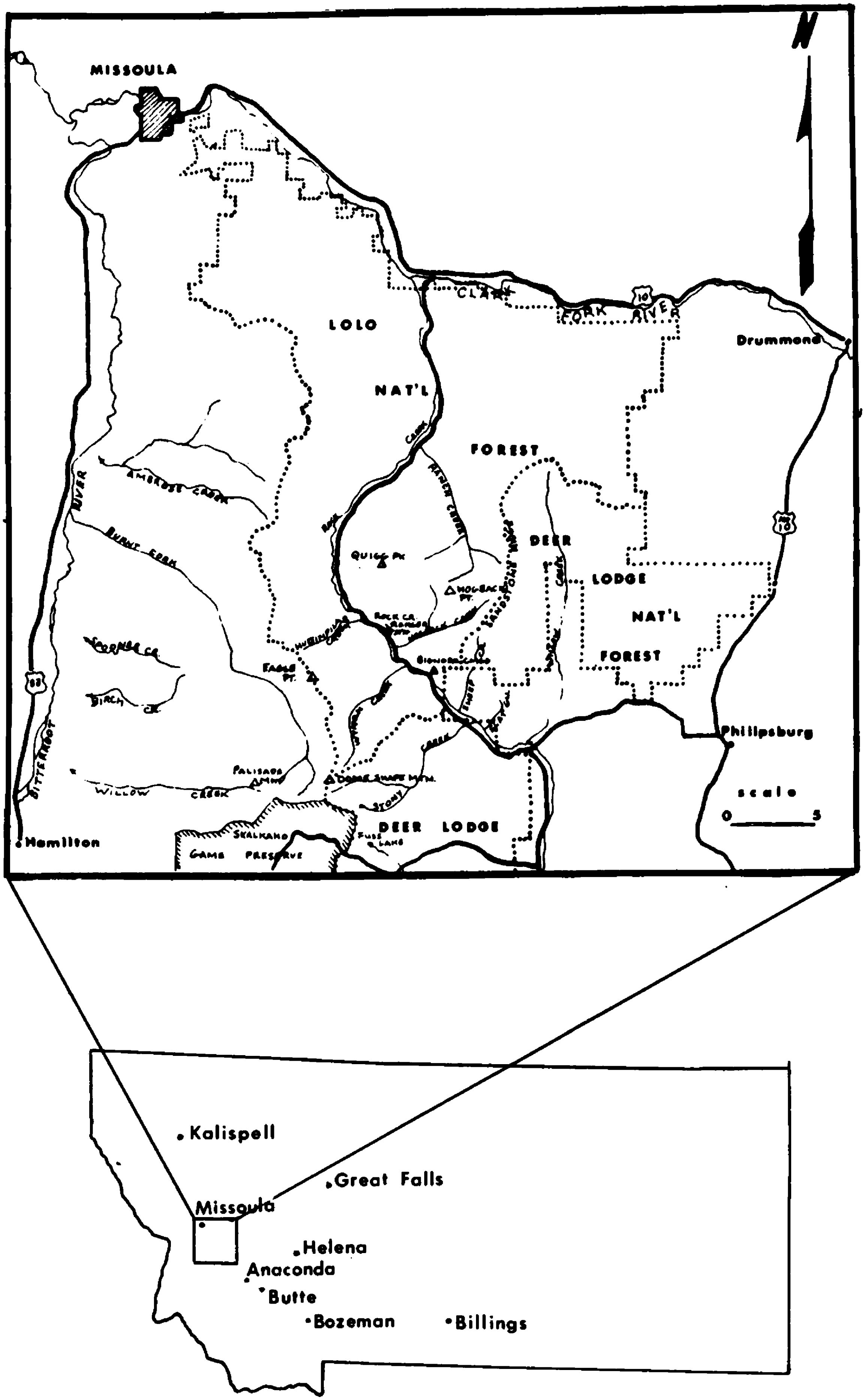

N
MISSOULA
LOLO
NAT'L
FOREST
CLARK FORK RIVER
10
Drummond
DEER
LODGE
NAT'L
FOREST
QUIGG PK
HOG BACK PT.
AMBROSE CREEK
BURNT FORK
RIVER
BITTERROOT
93
BIRCH CR.
WILLOW CREEK
PALISADE MTN
DOME SHAPE MTN.
STONY
DEER LODGE
SKALKAHO
GAME PRESERVE
FUSE LAKE
Philipsburg
scale
0
5
Hamilton
Kalispell
Great Falls
Missoula
Helena
Anaconda
Butte
Bozeman
Billings

Fig. 3. The Rock Creek winter range.

Wimmingtott
Bighorn Campgd.
Creek
Cuprum
Exclos. 5
Gulch
Trans. 8
Exclos. 4
Beaver Rn
Trans. 7
Trans. 6
Sheep
Gulch
Windiags
Trans. 5
Mill Gulch
Juno
Gulch
Square Book Resource Cabin
Wyman Rn
Exclos. 3
Flat
Trans. 4
Creek
Scatchman
Sawpit
Gulch
Leaf
Upper
Trans. 1
Exclos. 1
Exclos. 2
Trans. 2
Trans. 3
Jarvis
Rhinehart
Gillies Bridge
Rock
Neal Rn
Gulch
Trail
SCALE
0
1

and inability to retain water. Due to a paucity of fine materials, such as clay, climate and compaction can have a marked xerifying effect on vegetation supported by these soils (Dunmaier, pers. comm.).

Extremes of climatic conditions typify much of western Montana, including the Rock Creek area, and thus averages can be misleading. The winter of 1965, the beginning of the bighorn sheep decline, has been described as cooler and wetter than normal (Aderhold, MS)--ideal conditions for producing poor physical condition in the sheep (Part V: Nutrition, Condition, and Growth) and for an increase in lungworm and bacterial pneumonia. The winter of 1966-67 may be characterized as mild but long, with snow flurries extending through May. The winter of 1967-68 was short but very cold with attendant snow accumulation during December and January.

Aderhold (MS) summarized the precipitation and temperature data for the Philipsburg ranger station, which is the nearest permanent weather station to the Rock Creek winter range. For comparison, I installed a weather station containing a seven-day thermograph at the Neal Ranch on Rock Creek and maintained it during January, February, and March, 1968. The mean minimum temperature at Rock Creek was 0.5°F. less than at Philipsburg, while the mean maximum temperature was 0.5° higher. The Rock Creek and Philipsburg data are quite comparable, the extremes being a bit more pronounced at Rock Creek.

Local differences in temperature can affect the distribution of game animals inhabiting an area with a variety of slopes, aspects, elevations, and vegetation types (Taber and Dasmann, 1958). An attempt was made to determine temperature gradients with elevational changes.

Temperatures were read simultaneously in the Rock Creek Valley and on the winter range which rises to the northeast. Early morning temperatures at the bottom of the Rock Creek Valley averaged about 15° cooler than temperatures recorded on the hill at the same time. As the day progressed, if the sun were shining, the temperature in the valley would equal the temperature on the hill at about 11:30 A.M. and be about 20° warmer by 2:00 P.M. In other words, extremes of cold and heat were much more pronounced in the valley than on the hills above the valleys. As shall be seen in the discussion of the daily routine of the bighorn sheep, the sheep feed in the early morning coolness and bed during the warmer hours of midday. Generally speaking, the animals were nearly always located where temperatures were the warmest. During snow or rain, the animals would bed in the timbered draws.

Cloudy days seem to equilibrate the temperatures for the entire study area for the greatest portion of the day. If the day were cloudy, temperatures in the valley and on the hill would be equal by about 10-11 A.M. and remain about the same throughout the afternoon.

Year-round access is provided by Highway 10 via Drummond and Philipsburg and the gravel county road 348 which is snowplowed as far as the Brewer ranch (Figs. 2 and 3) during the winter.

The major form of land use in the study area is cattle ranching. The ownership of land on the winter range is presented in ~~Table 2~~ Table 1.

It is significant for the big game management policies that over 61% of the land which is considered key winter game range and 31% of the key bighorn sheep winter range is in private ownership. However, the importance for the wildlife of small ownerships such as the 1.9% of the game range owned by Mr. Parfitt and the 14% owned by Messrs. Boomer and Brewer are out of proportion to their small percentage of total game range.

A History of Land Use on Rock Creek

Michael Aderhold (MS) has surveyed the history of the Rock Creek region and much of the history in this discussion of the implications past land uses have had for the large mammals of the study area are distilled from his work. In addition, the present author has consulted source materials from the University of Montana library and has conducted personal interviews with residents and others familiar with the changes which have occurred on Rock Creek over the years.

Although the validity of recollections and accounts found in the so-called "mug books" (local histories financed by soliciting personal histories and pictures or "mugs" of those who appear in these books) is open to question, the accounts used in the present study were generally corroborative.

The Rocky Mountain race of bighorn sheep (*Ovis canadensis canadensis*), has inhabited this region for about 5000 years (Aderhold, MS). Prior to white settlement the sheep had extensive winter ranges throughout western Montana as evidenced by sheep skulls found in the hills overlooking Missoula and the adjacent Bitterroot drainage.

The fur trapper, Alexander Ross, and 144 of his party, subsisted on wild sheep during the spring of 1824 at Sula, 30 miles southwest of the present study site in an area which has not supported sheep in recent times.

The actual winter range on Rock Creek has undergone a similar shrinkage (Fig. ~~15~~ 14) according to reports of long time inhabitants.

The Flathead Indians were the first humans known to visit the Rock Creek area. The Indians prized the bighorn as a great delicacy, source of clothing and implements, and possibly an object of religious worship--sheep horns were pounded into certain trees in the area (Weisel, pers. comm.). These people obtained the horse about 1730, increasing the efficiency of their hunting. Also, horses competed for forage with the native ungulates. Having acquired the horse, the Flatheads established permanent trails for seasonal treks to the plains east of the continental divide to hunt bison with the Nez Perce Indians. Two of these trails passed through the vicinity of the Rock Creek winter range; they were also used for access to the bountiful game of the upper Rock Creek region. The efficiency of the mounted Flathead as a hunter is attested to by the decrease in game in the Bitterroot area by 1850, before the white man had any real impact. There are at least two Indian campsites bordering the Rock Creek bighorn winter range which were used by Indians as late as 1910 (Aderhold, MS).

Mining activities opened this portion of the Northwest to the first major influx of people of European culture. Their activities have left a mark on the land to the present day. The first prospectors worked Rock Creek in 1859. Twelve miles east of the study site, Hector Horton discovered silver in 1865 and the town of Philipsburg, the present county seat, was founded. Sixteen years later the Granite

Mountain Lode was developed at Philipsburg and over the next three decades yielded over $50,000,000 worth of silver and supported over 6,000 people.

A supply road was built from Missoula to Philipsburg in the early 1880's to exploit the Bitterroot-Missoula region. This road paralleled the sheep range, exposing the area to its first heavy traffic. Hundreds of horses, which were used for the mines, supply wagons, and personal transportation were wintered on range also used by the Rock Creek sheep, which created a competition for the forage species.

During the 1880's the Northern Pacific railroad reached the mouth of Rock Creek. The miners at Philipsburg and Granite and the railroad workers required meat, which was supplied by market hunters. The killing of wildlife for the market reached a high point in the winter of 1889-90 when 300 deer were reported killed on Rock Creek. Bighorns were said to be more plentiful than deer prior to 1895. The sheep are more visible and tend to winter closer to the valley through which the road travels, and therefore are more ~~vlunerable~~ vulnerable than the deer on the winter range. Probably the bighorn sheep were killed in at least equal numbers, but these are not recorded.

In pristine times wolves hunted the bottoms and grasslands and posed little threat to the sheep which utilized the cliffs as escape terrain. However, the cliffs border the creek and road, rendering the bighorn sheep particularly vulnerable to human hunters. The sheep, much to their present disadvantage, have not been able to alter the habits which evolved over the centuries in response to the predation by wild carnivores.

The relative abundance of predators in 1884 may be indicated by figures showing the sum of $12,000 paid as bounty for 568 bears, 146 cougars, 5,450 wolves, and 1,774 coyotes in the state of Montana. The last pair of wolves on upper Rock Creek were diligently pursued and killed by residents, hounds, and by government trappers in 1918 after a chase of several days' duration.

I have attributed the decline of the Rock Creek bighorn sheep in 1915 primarily to excessive hunting during the 50 years prior to 1915.

Old-timers in Missoula noted that about 1890 many wild sheep died due to "scabies," possibly contracted from the psoroptic mite of domestic sheep which were introduced in the Bitterroot Valley in 1867. The domestic sheep became very common after their introduction and numbered about 40,000 in 1876 and 260,000 in 1881 (statewide). We have a report of domestic sheep being raised on the winter range area about the turn of the century. Bitterroot Valley flocks would also be in contact with Rock Creek bighorns on the summer range.

The discovery of a rich placer in 1893 at Basin Gulch, which empties into Rock Creek on the winter range, filled the immediate area of the winter range with prospectors for gold and later sapphires until about 1910. Evidence of their industry can be found all over the winter range in the form of abandoned mine shafts and prospect pits. The miners took what food the land could provide, as Philipsburg was a two-day wagon journey away. These activities were responsible for the closure to hunting of bighorn sheep in 1903--evidence of their declining numbers (Table 43).

The Forest Homestead Act of 1906 and its liberalization in 1912 brought a rush of settlers to the Rock Creek Valley. At this time there were seven to ten times as many people living in the area as there are now. The primary holding in the area today, the Wyman ranch, was formed by the consolidation of eight small homesteads. Too little capital, experience, and land led to abuse of the land resource. The result was an exodus of the homesteaders during the late 1920's. It was during the 20's that all game reached its lowest ebb in the Rock Creek Valley because of overhunting and overgrazing by domestic stock

There was very little enforcement of game regulations during this period. Records indicate that a total of eight wardens enforced game regulations for the state of Montana in 1901-1904 (Scott, 1904: 177). They made 46 arrests during the entire period. Five arrests were made for big game violations in 1904, none in Granite County.

The Silver Panic of 1893, the exodus of the homesteaders, and the Depression resulted in what is today the major form of land use--the small (1,000-10,000 acres), stable cattle ranch worked by a resident owner. The effects of extant ranching operations on the vegetation of the study area are noted in the range section. At present about 250 cow-calf pairs are grazed on the bighorn sheep winter range for six to eight months each year, and two dozen horses are wintered on the sheep range.

Game increased during the 1940's, reaching a new peak. At this time, I estimate that the bighorn sheep occupied the present winter range at a density similar to that of prehistoric times. However, the present winter range represents only a portion of the contiguous area originally used by sheep during the winter. Therefore, the total number of sheep in the late 1950's and early 1960's was lower than before the white man arrived. Conversely, the mule deer, which are better able to disperse through timber to new patches of grass, and to tolerate the ecosystem alterations of man, have recolonized areas where they had been eliminated and today are at numbers equivalent to or greater than ever before.

From October to May about 700-800 mule deer reside on the winter range. Today, an important portion of the winter range is assured of remaining in poor condition by the winter grazing of about 15 horses.

The reduction of the carrying capacity of the bighorn sheep winter range on Rock Creek has resulted from several interacting, simultaneous processes. Heavy overgrazing in the early 1900's has presumably been the cause of an invasion of big sage. The oldest sage plants on one big sage stand, sampled in 1967, are 45 years old. This correlates with the heavy local overuse of the range resource due to the homesteads in the second and third decades of this century.

For whatever reasons, this winter range supports little other shrub growth. There are very few chokecherry, serviceberry, or snowbrush browse plants which are commonly found on similar ranges in southwestern Montana. This lack of browse is reflected in the feeding habits of both the sheep and deer, and results in a low nutritional plane (Part V: Nutrition, Condition, and Growth).

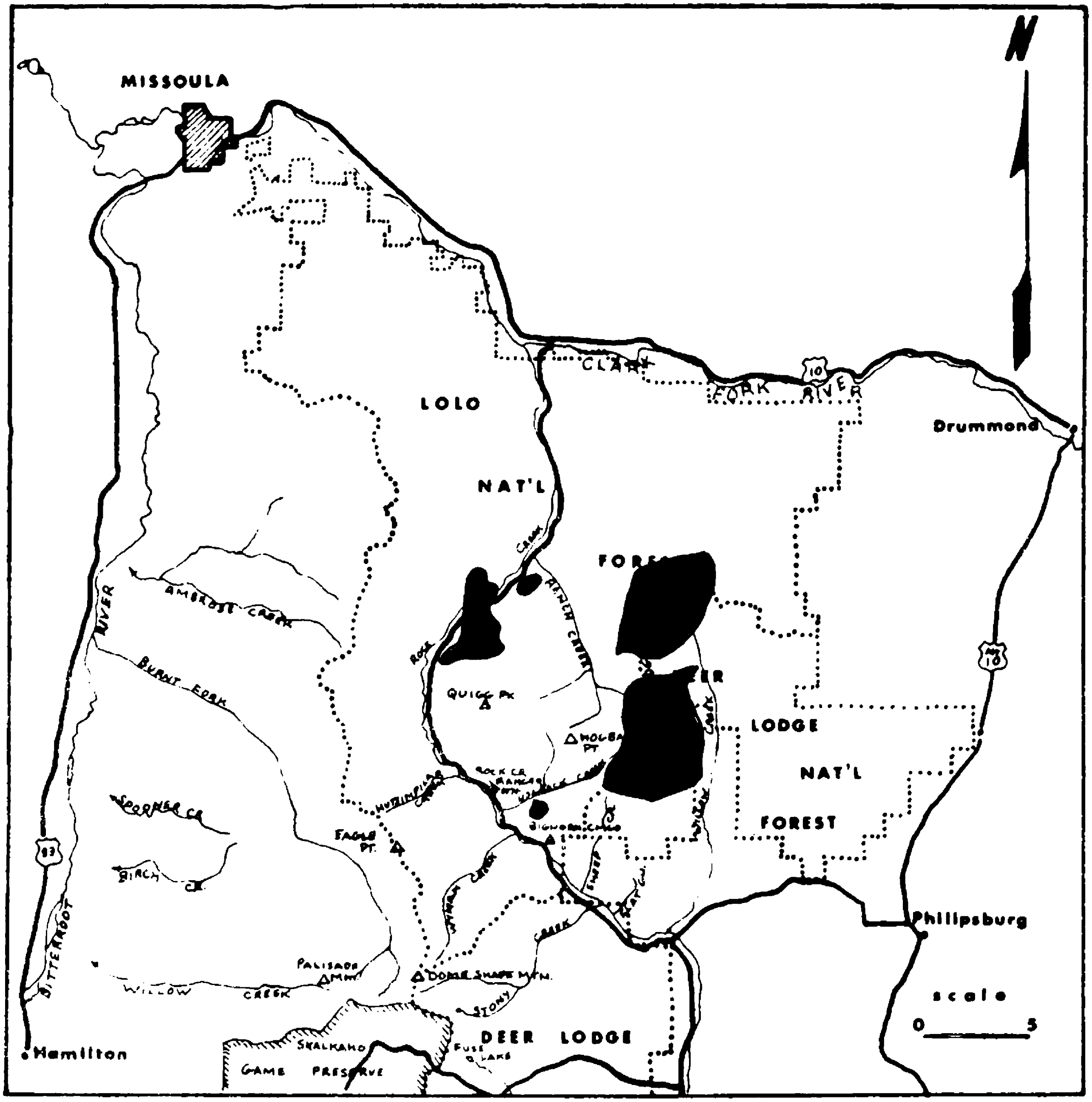
The population of bighorn sheep decreased from nearly 200 individuals in the early 1960's to about 15 today. Reports indicate more bighorn sheep than deer in the 1890's. Now there are approximately 70 deer for each bighorn in the area.

The Forest Service has become increasingly effective in controlling fires. Fig. 34 shows the extent of forest fires in 1919 for the Lolo National Forest portion of the Rock Creek area. During the extremely dry fire season of late summer, 1967, no fires large enough to be seen on the map occurred on Rock Creek. Tree borings indicate a fire frequency cycle of 30-40 years until the last major fires swept the area 50-60 years ago. The spread of trees into the grasslands, illustrated in Figs. ~~38~~ 35 and ~~39~~ 36, evidently has been accelerated by our control of natural and man-caused fires.

Defoliation of forest trees due to insect damage has also been the cause of recent intensive Forest Service control programs on Rock Creek. In 1963 DDT was sprayed on the presumed summer ranges of the deer and bighorn sheep that winter at Rock Creek. Malathion was sprayed on the entire region from the Sapphire crest to Sandstone ridge and from Skalkaho pass on the south to the Clark Fork River on the north in 1964.

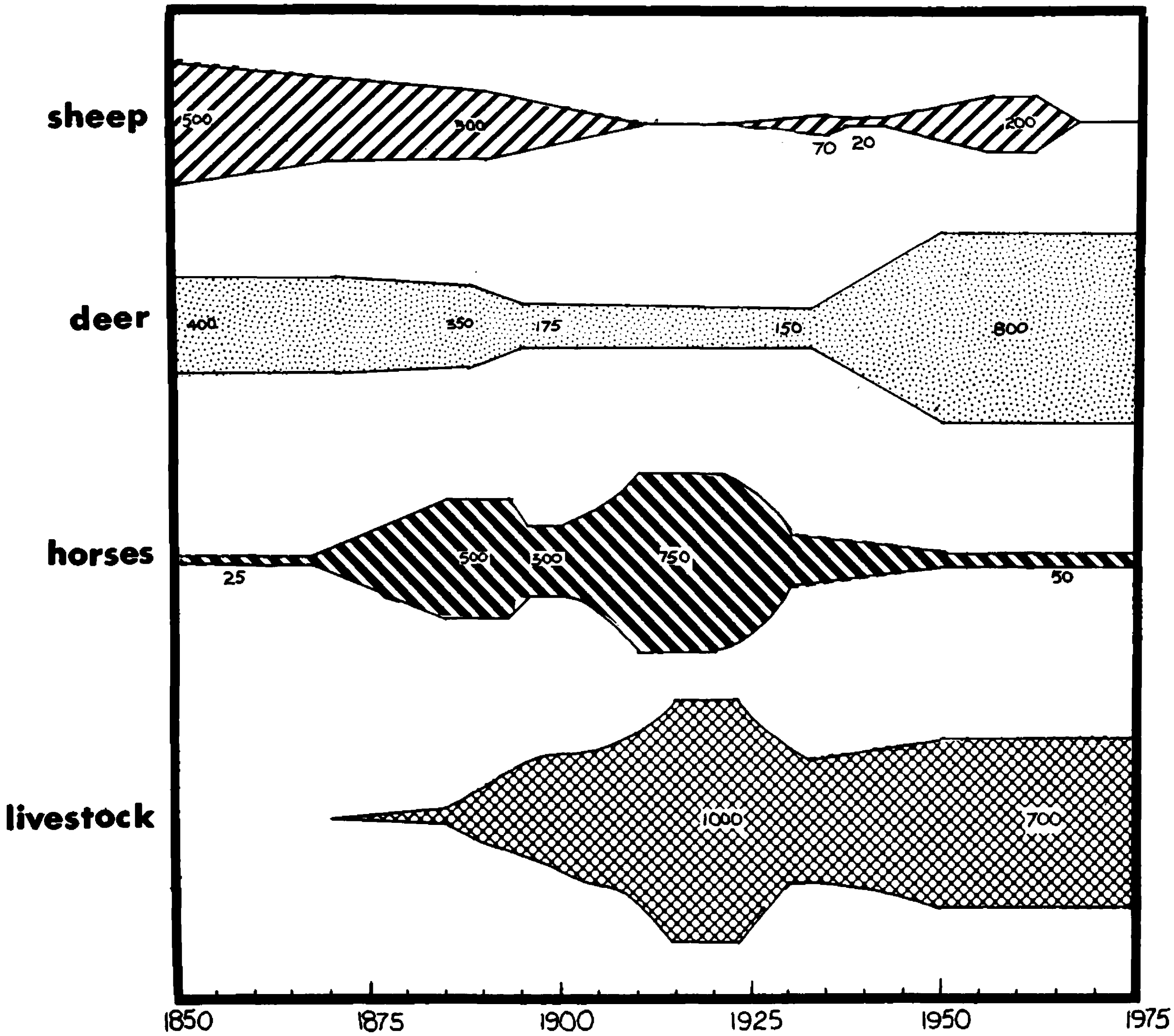
Since the turn of the century, the invasion of timber and coarser plants throughout the winter range has, in effect, reduced the forage available to the bighorn sheep and increased the less preferred "emergency" forage used by the deer, such as Douglas fir and juniper (Table 31 in Part IV: Vegetation and Forage Competition, Rumen Analyses). This trend has occurred simultaneously with a shift in the relative numbers of bighorn sheep and mule deer. The chronology of relative wild and domestic ungulate abundance is presented in Fig. 37.

Fig. 34. The 1919 fires in the Lolo National Forest portion of the Rock Creek drainage.


MISSOULA
LOLO
NAT'L
FOREST
CLARK FORK RIVER
Drummond
DEER LODGE
NAT'L
FOREST
LODGE
AMBROSE CREEK
BURNT FORK
BITTERROOT RIVER
SPOONER CR
BIRCH CR
QUIGG PK
EAGLE PT
PALISADE MTN
DOME SHAPE MTN
WILLOW CREEK
STONY CREEK
SKALKAHO GAME PRESERVE
FUSE LAKE
DEER LODGE
Hamilton
Philipsburg
scale
0
5
N

1919 Fires

Fig. 37. Relative chronological abundance of major ungulates on the Rock Creek winter range.



Relative Chronological Abundance of Major Ungulates on the Rock Creek Winter Range

The effects of fences, roads, hunting, traffic, and logging on the behavioral patterns of the bighorn sheep of Rock Creek have not been determined. It would be premature to state that such innovations are, *a priori*, detrimental to the sheep. However, the increasing sensitivity, over the past 14 years, of the sheep to any nearby unnatural disturbances (Part III: Behavior) suggests that long-term and intense disturbances occurring in the heart of the winter sheep range could be detrimental to the sheep.

Cultural practices and inherent attitudes of the white inhabitants have worked in concert to functionally eliminate the large predators on the study site. Mountain lions and wolves were the primary predators. A Fish and Game Commissioner's report of 1904 notes that lions were the major predators of bighorn sheep in the area. One possible effect of predator control measures could have been to increase the deer population which absorbed much of the predation. The ascendance of the major competitor for forage has undoubtedly had an adverse effect upon the bighorn population (Part V: Nutrition, Condition, and Growth).

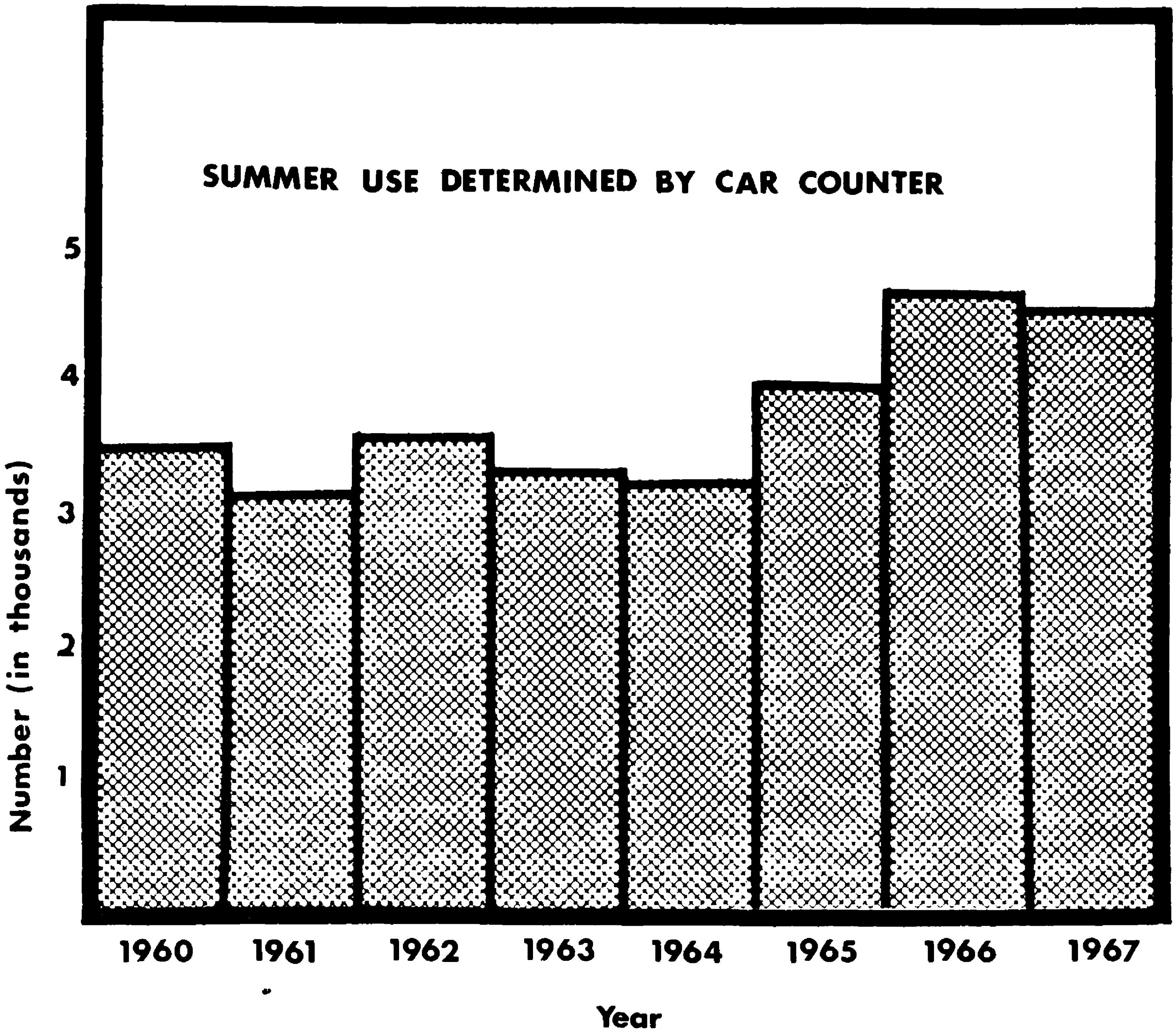
The intense agricultural activities of the homestead boom caused the lush riparian growth to be cleared and reclaimed as irrigable pasture. This further restricted the winter range of the sheep and particularly the deer, and served to intensify the competition between the species. The browse in the bottoms had afforded a critical food supply for bighorn sheep in particularly heavy winters when grazing was impossible due to heavy snow cover.

During the 1960's recreational use of the Rock Creek area has been accompanied by the development of ten public campgrounds by the Forest Service and a considerable investment in summer homes. The primary recreational use, the excellent trout fishery, has resulted in the designation of Rock Creek as a "Blue-ribbon" trout stream, and has resulted in national acclaim. Fig. 38 shows about a 30% increase in visitor use occurred between 1960 and 1967. This was based upon a car counter placed at either end of the Rock Creek road in 1967. The increase would have been even greater had not the forest been closed to public use for 18 days due to an extreme fire danger period which occurred during the prime recreation period of late August in 1967.

Table 43 (from Aderhold, MS) presents the history of bighorn sheep hunting on Rock Creek. The bighorn sheep do not appear on the winter range until October and are affected more by the deer and elk hunters in the fall and more recently, by snowmobiling during the winter, than by summer fishing. Recent studies in Colorado have noted the problem of harassment of game on the winter range. This factor is amplified by the occurrence of bighorn sheep breeding and associated activities during the hunting season, and by the sensitivity of the bighorn to human interference (Part II: Population Dynamics).

A sheep hunter in 1962 saw a total of three deer hunters and two other sheep hunters in five days of weekend hunting. In 1966 a bighorn sheep permittee reported seeing seven deer hunters in one day although he had actively hunted the area each weekend of the season. Last year the estimated deer harvest was about 125 animals, and some 60 hunters were counted on a five-mile strip of the winter range one day during

Fig. 38. Summer visitor use trends on Rock Creek as determined by car counts.


SUMMER USE DETERMINED BY CAR COUNTER
Number (in thousands)
1
2
3
4
5
1960
1961
1962
1963
1964
1965
1966
1967
Year

November. Hunting pressure varies with prevailing socioeconomic conditions in this area and was particularly heavy in 1967, due to the copper strike in the nearby mining and smelter towns of Butte and Anaconda. Bighorn sheep have been the victims of hunter errors as evidenced by a three-legged ewe seen during the past hunting season. In addition, poaching as a form of recreation results in an estimated annual loss of four to six sheep.

PART II: POPULATION DYNAMICS OF THE ROCK CREEK BIGHORN SHEEP

Literature and Methods

In trying to determine the potential productivity of a natural population, Buechner (1960:75) calculated the maximum growth rate (r) for bighorn sheep, based upon their biotic potential, using the growth equation $N_r = N_o e^{rt}$ (Odum, 1959:178). The "r" value of populations which had been transplanted into suitable habitat exceeded the calculated "r" of 0.258, during the growth phase of the population.

Recent evidence (Buechner, 1960:78; Smith, 1954:55; Woodgerd, 1964) indicates a minimum breeding age of one-and-a-half years for bighorn sheep in optimal habitat. Buechner calculated the theoretical rate of maximum increase of a bighorn population (r) based upon many field studies which have indicated a minimum breeding age of two-and-a-half years. Presumably most populations of bighorn sheep live in less than optimal habitat.

Lamb mortality is extremely high. On the other hand, the chances of survival are very good for sheep surviving the first year. Yearlings will generally be added to the breeding population. Hibbs (1968) in Colorado noted that early summer lamb to ewe ratios would approach 80:100 while classification of animals for the same areas in the fall would reveal ratios as low as 10:100. Taber and Dasmann (1957) calculate a 70% loss of lambs in the Dall sheep of Mt. McKinley based upon Murie's (1944) population data, and only a 10% loss of yearlings.

Although sex ratios at birth are about equal (Woodgerd, 1964), a gradual increase in the proportion of adult males will occur with age

(Murie, 1944:116; Woodgerd, 1964). Some evidence to the contrary has been presented by Cowan (1950:583, 587) who observed 44% males in an unharvested Canadian population. The longer life-span of males would tend to counteract high productivity in polygamous populations, thereby reducing the "r" value of unhunted populations.

Recent evidence (Spaulding, 1966; Neal, pers. comm.) indicates that twinning may also occur in healthy bighorn populations. It is noteworthy that lamb to ewe ratios (calculated for the natural populations which approximated the model) include nonbreeding and two-year-old females. Therefore, the maximum possible ratio is 60:100 rather than 100:100 (assuming no twins). To interpret field data in which adult ewes, yearling males, and two-year-old females are often confused, Buechner (1960:87) suggests allowing for the inclusion of yearlings with breeding ewes in some studies by subtracting 28% from the total ewe count. To allow for the inclusion of yearlings and two-year-olds of both sexes, he subtracts 58%. This procedure will not be followed in this study because the mortality of lambs approaches 70% in many populations. Thus, to include the yearling and two-year-old age classes based upon a purely mathematical treatment would enormously misrepresent the actual field situation. Mortality percentages should, if possible, be calculated for each herd, and a correction factor can then be derived. For example, if 70% of the lambs die in a particular herd, only 30% of the maximum possible yearling component of the entire herd (which constitutes 28% of the herd) should be used as a correction factor. The correction factor would be 30% of 28%, or 8.4% yearlings expected for a population in which 70% of the lambs die. Even with yearling mortality considered, the correction factor would be an approximation at best because the yearlings do not all die at the beginning of the year. The period of highest mortality should be considered in employing any correction factors.

Comparison of the different lamb to ewe ratios of different studies can be assumed as indicative of the relative productivity of the herd. An average of corrected lamb to ewe ratios for various bighorn sheep populations is about 79:100, the uncorrected figure of field observations being 58.5:100 (Buechner, 1960:81). These figures do not consider the rate of lamb mortality in different populations which, as indicated, seems to be very heavy in declining populations.

As Buechner (1960:79) notes, the rate of increase in deer is approximately twice that of bighorn sheep, allowing a greater flexibility in response to environmental factors through greater variations in natality.

To assess wild sheep populations, mortality must be measured. The mortality rate, or turnover rate, produces the leveling off of the asymptotic growth curve and consequent oscillations. Buechner (1960: 82) arbitrarily defines a stable population of bighorn sheep as one in which the level fluctuates not more than 20% from one year to the next. Reasonably accurate life tables have yet to be constructed for mountain bighorn sheep (*Ovis c. canadensis*), although Bradley and Baker (1967: 142) and Murie (1944:123) have provided life tables for desert and Dall sheep respectively, which have proven somewhat applicable to Rocky mountain bighorn sheep populations. From Murie (1944:122), Buechner (1960:84) averages the sheep dying in each cohort and divides them by those which survive $\left(\frac{dx}{lx}\right)$, arriving at a mean mortality rate of 8.6%. Upon inspection of this population, it may be seen that the two- to nine-year-old classes weight the mean mortality. This group did not experience any significant declines although the very young and very old animals were subject to intense wolf predation. Murie's data present the only picture we have of the dynamics of a native sheep population under natural conditions including natural levels of predation. These data are useful in understanding the dynamics of bighorn sheep populations, such as that of Rock Creek, that exist in an ecosystem which has been extensively modified by modern man and exhibit mortality in age classes not indicated by Murie's work.

The bighorn sheep of Rock Creek have been partially censused and classified since 1954. The data were summarized by Aderhold (MS) and amended by myself. Intensive census and classification work has been conducted for the two years of this study. Methods involved attempts at total counts by air employing a Cessna tri-pacer, age and sex ratio counts during the field studies of 1966-67 and 1967-68, and an annual census conducted by a senior class of wildlife management students at the University of Montana and other interested persons on 28 January 1967 and 25 February 1968. The "annual" census by University personnel has been conducted periodically since 1956 (Aderhold, MS).

During the course of the field work, all bighorn sheep remains were submitted to the museum at the University of Montana. An attempt on 27 April 1968 to recover any winter-kill sheep or previously overlooked bodies was again aided by the senior class in wildlife management and members of the Wildlife Club of the University of Montana.

Identification in the field was aided by 9x30 Bushnell binoculars, a 20-power Bushnell, a 20-power Bausch and Lomb, and a 20-60 variable power Bausch and Lomb spotting scope.

An analysis of records kept by the Montana Department of Fish and Game yielded the numbers of successful bighorn permit holders for each year's hunt of the Rock Creek herd since the initiation of sheep hunting in the area in 1954.

During the last year of the study, 15 sheep were seen with enough regularity to enable a degree of individual, and, particularly, band identification. The dynamics of these sheep, their number, composition, movements, and intragroup relationships were thus fairly well worked out for the period between January and April of 1968.

Population Density

There were between 150 and 200 bighorn sheep on the winter range annually between 1960 and 1965. Details of the various counts are presented in Table ~~3~~ 2. The counts conducted by Fish and Game Department and University personnel excluded the northern third of the winter range where 20-35% of the sheep seemed to winter. This estimate is based upon the distribution data secured during the winter of 1966-67 and from observations of reputable individuals who have frequented the area for the past 15 years, such as Dr. P. L. Wright and Mr. Robert Neal. However, the distribution of sheep during the winter of 1966-67 should be confirmed by future observations as it may not be typical

(P. L. Wright, _pers_. _comm_.). Omission of this upper portion of the range would tend to reduce the number of mature males present in the herd composition counts. About 1957, Harold Wyman, a long-time resident and ardent benefactor of the Rock Creek bighorns, took 16 mm. motion pictures of a band of 72 (by my count) sheep behind his ranch. During this same period, several individuals (including Game Warden Stuart Markle and Ranger Hoke Grotbo) saw over 50 sheep on Jimmy Leaf mountain. The possibility that these counts represent different bands is likely. These figures would also indicate a total population approaching 200 individuals.

The highest number of individual sheep ever counted in a single day by ground census was 130 in 1960. A correction factor of 45% was obtained by calculating the per cent difference between the 1967 census (47 sheep) with the fairly accurate figures obtained during the course of the field work of that winter (62 sheep). Using this correction factor, one can add 59 sheep to the 130 censused in 1960. If sheep occupying the uncensused portion of the winter range were added to the 189 sheep calculated, the total would probably exceed 200. During the fall of 1962, an employee of the Johnson Flying Service made several helicopter flights to count and locate sheep prior to the hunting season for which he had drawn a sheep permit. This man claims to have counted over 200 individual sheep. Thus, 200 bighorn sheep is a realistic figure for the maximum number of sheep found on the Rock Creek winter range since the turn of the century.

At this maximum figure, the density of sheep would approach 0.18 sheep per acre (115 per square mile) for the 1,088 acres on which the bighorn sheep normally winter. When 62 sheep inhabited the winter range during the winter of 1966-67, density was about .057 sheep per acre (36 per square mile). Last winter when 15 sheep were counted, sheep density was about .014 sheep per acre (9 per square mile).

The sheep and deer tend to form bands which occupy discrete portions of the winter range. For the past two winters about ten sheep occupied the south and northwest faces of Jimmy Leaf mountain, and another ten sheep occupied a portion of section 22 in the Deer Lodge National Forest. Density would be about .1 sheep per acre at these sites (or about 64 sheep per square mile).

For the 800 mule deer occupying 4,048 acres, density is about .198 deer per acre (127 per square mile).

In areas of deer concentration, densities approach .4 deer per acre (256 deer per square mile).

Natality

Reproductive success has been used as an indirect method of determining range condition and the nutritional plane of ruminants foraging on the range (Morton and Cheatum, 1946: Taber and Dasmann, 1957; and others). Investigators of reproduction in big game mammals have found that virtually all mature animals in good physical condition breed (Smith, 1954:58; Wright, _pers. comm._), conceive, and carry the young to full term. For mule deer, Robinette reports a 3.25% loss between implantation and mid-pregnancy, and a 1.66% incidence of atrophic fetuses in late pregnancy. Nellis (1964:12) found 90% of the Bison Range mule deer to be pregnant.

During the two years of field work, only two ewes which could have been pregnant were autopsied. Given the odds against finding an intrauterine mortality and the similar improbability of finding a mature female which was not pregnant, I was surprised and concerned to find a mummified fetus in a five-year-old female illegally shot on 5 May 1967 and no fetus in a ewe found 28 May 1967 which had been dead about three weeks.

Lambing has traditionally taken place in the cliffs of the winter range (Miles Rotta, Matilda Wyman, and Robert Neal, *pers. comm.*). However, by the lambing period (mid-May to mid-June) of 1967, the majority of the sheep had departed for the summer range--an unheard of occurrence according to the local sources referred to above. This apparent alteration of the place, and possibly the time, of parturition eliminated any chance of determining post-natal lamb to ewe ratios immediately after parturition.

Population Structure and Ecology

Observations of sheep, usually in the grassland habitat type, were conducted throughout each winter of the study, and for the six resident sheep through the summer as well. Tables ~~3~~ 2 and ~~4~~ 3 give the uncorrected and corrected counts of the sex and ages of the bighorn sheep occupying the winter range for the past 14 years.

Table 2. Population structure of the Rock Creek bighorn sheep for years of classified counts prior to present study*

Year	Adult ♂♂	Adult ♀♀	Immature	Lambs	Total number counted
1954-55	55(16)	100(29)	?	38(11)	56
1956-57	29(?)	100(?)	?	46(?)	51
1960-61	23(14)	100(60)	17(10)	45(27)	130
1961-62	?	100(38)	?	61(23)	100
1964-65	60(12)	100(20)	?	35(7)	103
1965-66	31(9)	100(29)	?	28(8)	46

*The figures have been corrected to include the 10 yearlings included in the total of 24 males.

Table 3. Population structure of the Rock Creek bighorn sheep during the winters of 1966-67 and 1967-68*

Year	Adult ♂♂	Adult ♀♀	Immature	Lambs	Total number counted
1966-67	34(12)	100(35)	11(4)	31(11)	211(62)
1967-68	175(7)	100(4)	50(2)	75(3)	198(16)
					Total % herd decrease
% summer decrease of class	41.7	88.6	50.0	72.7	74.2

*Actual number of sheep in parentheses.

A tabulation of the dead sheep found during the course of the study is presented below (Table 4). Because a disproportionate number of adult females apparently die while on the summer range, these figures do not represent the classes of sheep as they appear in the living population, and therefore a life table was not constructed. Field work in progress at this time is expected to reveal the location of the summer range of the bighorn sheep. If current work yields bighorn sheep carcasses from the summer range, a life table at essentially the 100% exploitation level can be prepared similar to Andersen's (1953) for the roe-deer of Kalø. Three of the 19 adult females listed in Table ~~5~~ 4 died during the summer but on the winter range. All other sheep bodies, or the remaining portions of them, were also found on the winter range. The season of death in these cases was either the winter, or could not be ascertained. These ewes were found in October and had died during the summer and so would not influence the impression of heavy summer mortality in this class of sheep.

Table 4. Classification of sheep found dead or shot on the Rock Creek winter range since 1965*

Age	Sex			
	♂♂	♀♀	Unknown	Total
0-1	..	..	3	3
1-2	..	..	1	1
2-3	4	2	.	6
3-4	2	7	.	9
4-5	3	7	.	10
5-6	2	3	.	5
6-7	1	..	.	1
7-8	..	..	.	..
8-9	1	..	.	1
Total	13**	19	4	36

*Since the decline--1965-68 inclusive.
**Including four hunter-killed sheep.

The population data presented in Tables ~~1, 2~~ 2, 3, and ~~3~~ 4 describe a population in the midst of a decline. Briefly, the results are summarized below:

1) A loss of nearly 78% of the population occurred during the summer of 1967 (Table 4). The failure of field workers to find (during the fall, winter, and spring of 1967-68) any appreciable per cent of the 46 sheep which failed to return to the winter range tends to reinforce the picture of a severe summer loss.

2) A distinctive feature of the summer loss appears to be the vulnerability of females between the ages of three and six (Tables 3 and 4). The stresses attendant to gestation, parturition, and lactation implicate nutritional deficiencies as a possible causative agent in the losses of bighorn sheep wintering at Rock Creek.

3) Only three of the 11 lambs seen during the winter of 1966-67 survived the summer. The 72.7% attrition rate is in excess of the rate expected in normal populations.

4) Based upon data presented earlier from Taber and Dasmann (1957) for a stable population of Dall sheep, birth rates are low and death rates are high in the Rock Creek bighorn sheep.

Taber and Dasmann (1957) constructed survivorship curves for males and females of three populations of blacktailed deer and roe deer, red deer, and Dall sheep populations. Both sexes of all populations show heavy first year mortality.

Subadult females show little mortality after the end of the first year. Coincidental with the production of young, females of all populations except Dall sheep show an accelerated mortality which remains fairly constant until old age. The inverse relationship between reproduction and survival, in females, is related to nutritional deficiencies due to forage competition on fully or overstocked ranges.

The female Dall sheep do exhibit a slightly higher mortality and shorter life span than males; however, the curves are quite similar to each other when compared with the Cervid populations. Taber and Dasmann (1957) ascribe this high survival of female Dall sheep to the intense wolf predation which removed the very young and very old and kept the population below the carrying capacity of the range.

Taber and Dasmann (1957) feel that "most of the differences between these various populations are not inherent in the species, but rather are imposed by environmental conditions . . . if Dall sheep were not culled by predators, the population would presumably be limited by food supplies, and the mortality among prime adults would increase accordingly."

Another interpretation of the data presented for the Dall sheep of Mt. McKinley National Park is suggested in the following discussion.

Mountain sheep populations are particularly sensitive to such density dependent mortality factors as lungworm and pneumonia (Buechner, 1960:104) and ordinarily harbor residual levels of lungworm and pneumonic bacteria (Buechner, 1960:104; Howe, 1966). For example, in the Tarryal (Colorado) sheep "it is inescapable that the disease mechanism functions as a population control, reducing the level when it becomes excessively high, and that it operates almost independently of the condition of range vegetation (Buechner, 1960:107)."

Geist (1967) describes mountain sheep following the retreat of glaciers in Asia and North America. They evolved in intimate contact with wolves. The effect of constant wolf predation on a bighorn sheep population would not only serve to cull the very young and infirm, but to keep the sheep, which are by nature gregarious, spread out upon the ranges they occupy. This would lessen the incidence of lungworm infection and dampen the rather violent oscillations typical of many mountain bighorn sheep populations in the United States where wolves have been functionally eliminated. Although at the time of Murie's study of Dall sheep in the late 1930's and early 1940's wolves were subject to essentially natural controls, today trappers and hunters have made severe inroads into some local Alaskan wolf populations, including that of Mt. McKinley (Atwell, _pers. comm._). Coincidentally, Dall sheep mortality has been recently seen (Atwell, _pers. comm._).

On at least six contiguous winter ranges of bighorn sheep in southern British Columbia, severe die-offs have occurred between 1964 and 1967 moving progressively northward. The enzootic was due to a _Pasteurella_-_Corynebacterium_-like pneumonia predisposed by heavy lungworm infestations. "Presumably, the disease was passed from one band or population from another by affected individuals mingling with others on the summer ranges (Bandy, 1968:9)." Wolves had previously been severely reduced on these ranges (West, 1955:96).

Buechner (1960:91) notes that one of the highest forms of self regulation of a population--territoriality--seems to function in one form or another in many of our wild ungulates, such as moose (Altmann, 1963) and blacktailed deer (Dasmann and Taber, 1956), but appears to be absent in bighorn sheep. He contends that for the bighorn which does not possess a strong antisocial mechanism for regulating density, the less sensitive, more "primitive" forms of population regulations, such as starvation and disease, are operative. Further, he notes that the most drastic fluctuations occur in the more favorable habitats, which can allow periodic build-ups to high densities. It appears that the bunchgrass ranges of the Rocky Mountain trench areas of Montana and British Columbia, including the Rock Creek area, would be among the milder and more productive bighorn sheep habitats.

The close association between the range expansion of bighorn sheep and the grassland habitats newly created in the wake of receding glaciers is chronicled by Clark (1964) and Geist (1967). The absence of spacing mechanisms in an animal which is so prone to density dependent decimating factors, such as lungworm and pneumonia, is an apparent paradox unless viewed in the context of an evolutionary response to an expanding habitat--namely, the distinctive lack of territory--a mechanism primarily adapted to provide for spacing of animals in a more finite habitat.

Although wolves were once common, the last wolf in the Rock Creek area was killed by a government trapper in 1918. The first known decline of the sheep in the area occurred in about 1915 (Miles Rotta, pers. comm.).

The healthiest populations of mountain bighorn sheep found today exist in the recently created habitats of still heavily glaciated portions of the far North. It is possible that in the older, restricted ranges of the more southerly mountains, such as the Rockies of the United States, the ultimate factors which limit the bighorn sheep relate to the absence of newly created habitat in which expansion can occur and the consequent decimation of the sheep by density dependent parasites and diseases. Actually, the extreme declines of sheep in limited habitat functionally serve as a mechanism whereby the bighorn can recolonize its former range.

The concept of carrying capacity based only on food and cover may thus be misleading when considering bighorn sheep populations. For wild sheep a more realistic concept of carrying capacity might involve some sort of index of predation--a minimum level of predatory pressure to effect both culling and dispersal and dampen the violent oscillations in populations so sensitive to density dependent regulating mechanisms. Possibly, both range condition and predation interacted aboriginally to regulate bighorn sheep populations. The deer populations studied by Taber and Dasmann (1957) do not appear to be as sensitive to these density dependent factors as do the bighorn sheep. Hence, the limitation of the range resource would result in the accelerated mortality of breeding female bighorn sheep seen on Rock Creek.

Mortality

The possible causative agents for the high mortality in Rock Creek bighorn sheep (especially in adult females) are reviewed below.

Disease and Parasites

The lungworm-pneumonia complex has been associated with often spectacular bighorn sheep die-offs ever since Hobmaier and Hobmaier (1930) identified the intermediate host of the domestic sheep lungworm, *Protostrongylus rufescens*, as a certain species of land snail, and Marsh (1938) showed the probability of a land snail intermediate host for lungworms of bighorn sheep, *P. stilesi* and *P. rushii*. Some notable sheep die-offs were: 1) The Sun River, Montana, herd dropped from nearly 700 head in 1924-25 to fewer than 100 individuals, eventually recovering to a population of about 600 sheep today. 2) The bighorn sheep in Glacier National Park in 1926-27 and 1936-37 declined from a population in 1917 of about 207 sheep to about 17 in 1937, possibly related to overconcentration due to fires and feeding (Buechner, 1960:98, 99). 3) The Pike's Peak, Kenosha, and Tarryall die-off of 1952-53 was probably the best documented. The total population prior to the die-off was near 1,500 sheep (Hunter and Pillmore, 1954). After the die-off, 200-300 sheep remained. Although sheep losses from lungworm infection are common, Marsh (1938) and Pillmore (1958) point out that lungworm infection is not always found in sheep which have died of pneumonia. Forrester and Senger (1964) note that since the establishment of the bighorn sheep herd of the National Bison Range in 1922, there have been two serious die-offs (1930 and 1940) with very low levels of lungworm infection.

The results of the autopsies conducted on the five bighorn sheep secured by Mike Aderhold and myself during the fall and winter of 1966-67 have been summarized by Aderhold (MS) and are presented below (Table 5). Included in this table are the results of three fecal samples collected April 5, 1968 and analyzed for parasite larvae by personnel of the Montana Veterinary Research Laboratory at Bozeman, Montana. A ninth sample was secured from a ewe found in 1966 shortly after its death and taken to the U. S. Public Health Service Laboratory in Hamilton for post-mortem examination.

Table 5. Incidence of lungworm in nine bighorn sheep of Rock Creek, Montana[1]

Age	Sex	Secured	Area	Degree of lungworm (larvae) infection		
				Descriptive	Larvae/gm feces	Baerman[6] exam
?	♀	1966	Rock Creek	no infection[2]	.....	..
3½	♂	10/ 3/66	Windlass	moderate	.....	..
3½	♂	11/13/66	Windlass	moderate	.....	..
4½	♂	11/29/66	Jimmy Leaf	very light	.....	..
8½	♂	4/14/67	Capron	light[3]	.....	..
3½	♀	5/11/67	Capron	light[4]	.....	..
?	?	4/ 5/68	Exclosure 3	mod.-heavy[5]	134.0	+
?	?	4/ 5/68	Exclosure 3	mod.-heavy[5]	33.7	+
?	?	4/ 5/68	Exclosure 3	no infection	0	-

Total per cent feces infected = 66-78%

[1]Unless otherwise indicated the analyses were done by Gerald O'Bryan, graduate student in parasitology, University of Montana.
[2]Ewe brought to USPH Laboratory, Hamilton, Montana, 1966.
[3]Reported as heavily infected based upon examination of the lungs by J. Brogger, D. V. M., Missoula, Montana.
[4]Reported as not infected based upon an examination of the lungs by Dr. J. Brogger.
[5]The descriptions were suggested by Dr. William Hawkins of the Veterinary Research Laboratory, Bozeman, Montana. When compared with the figures of Forrester and Senger (1964), which range up to 970 larvae/gm feces and average 160 larvae/gm feces, these infections would be described as light to moderate.
[6]The larvae migrate in a funnel and fall into fixative. This test is not quantitative.

Table 6. A comparison of Forrester and Senger's (1964) Rock Creek lungworm data with ten other Montana sheep populations

	% fecal samples with larvae	No larvae/gm	Mean lesion area of lungs (mm^2) [1]
Rock Creek	95	110	1137[2]
Other Montana populations	91	160	2332[3]

[1]From hunter kills of five other populations.
[2]1961 and 1962.
[3]1959, 1961, and 1962.

To relate the degree of lungworm infection of the Rock Creek sheep with other populations, data from nine other sheep herds (Forrester and Senger, 1964) are compared with the results of the analyses presented in Table 6 ~~5~~.

Forrester and Senger (1964) discuss the positive relationship of abnormally moist spring weather and high population density with infection incidence of the intermediate host land snails. They note that the areas in Montana in which the severest infections of sheep by lungworm are found, the Stillwater and Sun River regions, support the densest populations of land snail intermediate hosts.

As indicated by the per cent of sheep infected and the degree of the infection when present, the bighorn sheep of Rock Creek are not infected by lungworm to the extent most other bighorn populations of the state appear to be. Lungworm does not appear to be a causative factor in the decline of this population.

The light lungworm infection found in the Rock Creek sheep before and during the present die-off has some interesting implications. As noted earlier, Buechner divides sheep populations into 1) those which inhabit harsh environments and 2) those prone to extreme population fluctuations, which inhabit milder environments. The latter are the populations which I have suggested are dependent upon wolf predation to dampen the oscillations by decreasing the susceptibility to density dependent decimating factors. It is suggested that these populations, which inhabit the environmentally "milder" winter ranges, can be further classified into populations which are extremely susceptible to lungworm-pneumonia decimation, such as the Tarryall or southern British Columbia populations, and a few exceptions which seem to be controlled by regulating mechanisms other than lungworm, such as the National Bison Range and Rock Creek herds.

The latter two populations are quite similar in several respects: 1) They are in the same general region--the Bison Range supports the closest Montana population of bighorn sheep to the Rock Creek sheep. 2) Lungworm has not been implicated in the two die-offs experienced by each herd in the past. 3) Until the last eight years, the browse of the National Bison range was in a depauperate condition, similar to the Rock Creek winter range (Morris and Schwartz, 1957; Nellis, 1964:91). This was reflected in the grazing habits of the ungulates occupying both areas and has nutritional implications which are discussed later. 4) The climate of both areas is quite similar although there is a difference of about 2,000 feet in elevation. The 1967 mean annual temperature at St. Ignatius, adjacent to the Bison Range, was 47.7° F. and at Philipsburg, 41.3° F. Precipitation for the year was 13.31 inches at St. Ignatius and 14.70 inches at Philipsburg. 5) The species of land snails found on the National Bison Range and Rock Creek by Forrester (1960:27,28) do not seem to be the most acceptable hosts of the lungworm (Table 7).

Deroceras could serve as an intermediate host, but Pillmore (1958) found two species of *Deroceras* to be refractive to *Protostrongylus stilesi* and *P. rushii*, the two lungworm species which infect bighorn sheep. Snails of the families Pupillionidae and Valloniidae are the most significant intermediate hosts in the bighorn lungworm life

Table 7. Land snails found by Forrester on the National Bison Range and Rock Creek winter ranges

Bison Range	Rock Creek
Oreohelis stringosa	Zacoleus idahoensis*
Anguispira kocki	Derocerus laeve*
Vitrina alaskana	Quickella relideri

*Tentatively identified by Forrester.

cycle (Pillmore, 1958), and members of one or both of these families were found on the Gallatin, Many Glaciers, Stillwater, Yellowstone, Kootenai Falls, Sun River, Ural-Tweed, and Wildhorse Island ranges. The only two ranges on which they were not found were the National Bison Range and Rock Creek (Forrester, 1960:24).

It is possible, therefore, that the soils, vegetation, climate, or some other peculiarity of the site would influence the ecology of the land snail, lungworm, or sheep in such a manner as to reduce the importance of lungworm as a mortality factor for the bighorn sheep of the site.

Bandy (1968) formulates an index of parasitism based upon the frequency of occurrence of key parasites found in fecal samples of bighorn sheep prior to and after die-offs, and in populations in which die-offs did not occur. In Canada the relationship between pre- and post-decline parasite burdens suggested a predictive value for such an index. For populations such as those of the National Bison Range and Rock Creek, this index might not apply if, indeed, the parasite burden is not indicative of a potential population decline.

The identification of Pasteurella and Corynebacterium in many bighorn sheep dying of pneumonia had been considered a primary cause of bighorn mortalities in early investigations (Buechner, 1960:103). With the discovery of the importance of lungworm in sheep declines, these early diagnoses were discarded in favor of a theory which relates the early declines to a lungworm-pneumonia complex. The current feeling is that the lungworm infection predisposes the sheep to bacterial or viral pneumonia.

However, as has been pointed out earlier, several declines have shown mortalities due to bacterial pneumonia without a noticeable lungworm infection. This is particularly evident in bighorn lambs (Honess and Frost, 1942:98, 99; Forrester and Senger, 1964; Buechner, 1960:103). The role of bacterial pneumonia in bighorn mortalities is again undergoing re-evaluation. Safford and Hoversland (1960:266) reviewed the cause of death of 1,051 domestic lambs in Montana and found pneumonia to be the most common cause of death. They speculated that the "inability of weak lambs to expel amniotic fluid plays a part in the high incidence of pneumonia in lambs. The average age of death in lambs dying of pneumonia was 15 days." Post (1962) has evaluated several reported population declines and the loss of 17 bighorn sheep in two declines at the experimental pastures of the Sybille experiment station in Wyoming. He isolated ten strains of Pasteurella or Pasteurella-like bacteria from tissues and swabs collected from bighorn sheep, none of which were the same as five Pasteurella strains secured from domestic sheep. He felt that Pasteurella and not lungworm might be the primary cause of declines previously reported as being caused primarily by lungworm. Howe (1966:8) notes that lungworm is present in nearly all of the bighorn sheep, adults and lambs, at the Sybille Unit. However, the "effects of this affliction alone have not appeared to be serious until the onset of bacterial infections . . . enough evidence has been accumulated to show that bacteria such as Pasteurella spp. are undoubtedly responsible for most of the pathologic changes associated with pneumonia in bighorn sheep."

These reports of pneumonia in bighorn sheep not seriously afflicted ~~afflicated~~ by lungworm infections have also led to the implication that viral agents are involved in the disease process as is the case in domestic livestock and humans. Howe (1966:8) has isolated 18 strains of Pasteurella in bighorn sheep, and has also discovered significant titers against respiratory viruses in bighorn sheep, indicating that "these viral agents may be involved in producing pneumonia in these animals. It is likely that the effect of the viruses would be to increase the susceptibility of the animals to bacterial infection, enabling the rapid invasion of bacterial pathogens into the respiratory tissues."

How important bacterial and viral agents are in the mortalities of the bighorn sheep of the National Bison Range and Rock Creek has not been determined. However, the low levels of lungworm, the summer mortality, the stressed condition, and the poor nutritional regime (Part VI: Nutrition, Condition, and Growth), particularly the protein deficiencies, may contribute to sheep mortality and certainly warrant further investigation.

An attempt to assess the importance of bacterial organisms and the transmissibility of these organisms from domestic sheep to bighorn sheep was made in the spring of 1968. Nasal swabs were taken from 17 bighorn sheep of the National Bison Range and from ten adult domestic sheep of Mr. Chester Brewer which winter immediately adjacent to the Rock Creek winter range. The swabs were shipped on dry ice to the Veterinary Research Laboratory at Bozeman. The results are tabulated below.

Table 8. Bacteria cultured from nasal swabs taken from bighorn sheep of the National Bison Range and domestic sheep at Rock Creek

Bison Range bighorn	Rock Creek domestic sheep
Staphylococcus aureus	*Staphyloccus aureus*
Several other nonpathogenic bacteria	*Pseudomonos* spp.
	Lactobacillus spp.
	Bacillus cereus
	Bacillus spp.

The very young are particularly susceptible to infection by viral or other disease agents. The young possess a much smaller reserve of dietary nutrients than the adult (Humphrey and White, 1964:36). Dubos (1963) has established relationships between starvation and disease. He has found that protein deficiency leads to a greatly increased susceptibility to bacterial infection in young mice. Also, an increase in adrenal corticoids, which is typical in stressed animals, results in an increase in the susceptibility to bacterial invasion, such as *Corynebacterium pseudotuberculosis* in rats treated with cortisone (Humphrey and White, 1964:39).

Blood samples secured from the bighorn sheep of the National Bison Range and the domestic sheep of Rock Creek proved negative for Anaplasmosis, Brucellosis, and Leptospirosis.

In sum, the following conclusions may be drawn regarding the importance of lungworm and pneumonia as mortality factors in the Rock Creek bighorn sheep:

1) The Rock Creek bighorn population exhibits a low level of lungworm infection when compared to other, often thriving (i.e., Sun River) populations of bighorn sheep in Montana.

2) The level of infection may be related to the nature of the environment and its effect upon the distribution and density of the local snail intermediate host of lungworm.

3) In view of the poor physical condition of the Rock Creek sheep and the high level of stress (both of which are likely caused by nutritional factors discussed later) and the season of death, it seems possible that bacterial pneumonia (possibly predisposed or complicated by viral agents) is a more important decimating factor of the Rock Creek bighorn sheep than is lungworm.

The following description of the other parasites found in the Rock Creek bighorn sheep briefly brings up to date and summarizes data presented by Aderhold (MS).

Nosebots: Nosebots are relatively rare in bighorn sheep, and none were seen in the domestic or bighorn sheep autopsied during the course of this study. Nosebots were recorded in the 1966 ewe from Rock Creek autopsied at the Public Health Laboratory in Hamilton.

Ticks: In an attempt to determine the role of tick borne paralysis or fever in the Rock Creek sheep decline, Gene Hughes and Harley Sargent of the Public Health Laboratory in Hamilton collected 230 wood ticks (*Dermacentor andersoni*) and 44 winter ticks from vegetation and a ewe and placed them on hamsters at the laboratory (Table 9).

Attempts to isolate an infecting agent from the eggs of the ticks yielded no viral or rickettsial agents. Of 24 guinea pigs treated with tick innoculants, 11 showed lowered titers of spotted fever antibodies and one showed an appreciable titer of Q fever antibodies (caused by rickettsia) from *D. albipictus* (Aderhold, MS). Hughes and Sargent were surprised at the low number of ticks found on the study area and felt that the results were inconclusive.

Roundworms: Roundworm eggs found in the fecal samples were tabulated by Aderhold (MS) with the exception of the April, 1968, samples, which have been added by myself:

Table 10. Roundworm eggs recovered from fecal samples of the Rock Creek bighorn sheep

Sheep				Roundworms
Age	Sex	Condition at recovery	Date	
3½	♂	shot	10/ 3/66	*Trichostrongylus* spp. (Hookworm)
4½	♂	shot	10/24/66	none
2½	♂	shot	11/27/66	*Trichostrongylus* spp. *Nematodirus* spp. (Hookworm) *Trichuris* spp. (Whipworm)
8½	♂	found	4/14/67	*Trichuris* spp. *Nematodirus* spp.
5	♀	shot	5/ 8/68	*Trichuris* spp. *Skrjabinema* (*ovis*?)
?	?	live	4/ 5/68	*Nematodirus**
?	?	live	4/ 5/68	none*
?	?	live	4/ 5/68	none*

*Total gastrointestinal E. P. G. (flotation) = 4.

Protozoans: Aderhold (MS) lists

Eimeria	*arloingi*	in three of five sheep
E.	*crandallis*	in one of five sheep
E.	*intricata*	in one of five sheep.

Becklund and Senger (1967) lists 51 parasites of *Ovis canadensis canadensis* of which 11 have been found, to date, in the Rock Creek bighorn sheep.

In sum, this study has indicated that parasites do not adversely affect the bighorn sheep of Rock Creek to the degree they do in many other bighorn populations. Even the animals found in extremely poor physical condition did not exhibit the parasite burdens expected from a review of other populations.

Harassment

Visitor use for recreation is almost nil during the winter months at Rock Creek with one exception. Snowmobiling, the use of motorized over-the-snow vehicles for recreation, has become popular during the last several years. Throughout the mid-winter and spring of 1967, tracks of six-eight snowmobiles were noticed weekly on the open slopes between Jimmy Leaf mountain and the Neal ranch--an important segment of the bighorn winter range. The effects upon the bighorn sheep or deer are not known; however, harassment of this sort might well debilitate winter-stressed animals.

All of the families residing in the vicinity of the winter range own dogs and at least one harasses the sheep. For example, during a visit with the Parfitts in February of 1968, I watched five sheep and a dozen deer running back and forth across the face of Jimmy Leaf mountain, traversing the entire hill one-and-a-half times, being chased by the Parfitt's dog. Wild predators, such as the lion (Part II: Population Dynamics), will chase their prey only so long as the expenditures demanded have a reasonable chance of paying off. In contrast, the dog seemed to chase the game for sport and would give up only after he had exhausted himself.

Predation

The former abundance of wolves has been mentioned. Presumably, the last wolf on Rock Creek was killed in 1918. Mr. Robert Neal, a local rancher reports sighting and tracking a dark wolf in the West Fork Butte area in 1956. The West Fork Buttes are four map miles south of the Rock Creek winter range. Several wolf sightings have been reported since--the latest in June, 1968, by Harry Wade, a graduate in zoology from California, who has done some work on coyotes. These sightings are generally in the headwaters region of Rock Creek--Mr. Wade's at Ross' Fork is about 12 map miles south of the winter range. However, the effect any local wolves might have upon the bighorn sheep is minimal. No instance of wolf predation has been recorded during recent times.

Coyotes are capable of preying upon bighorn sheep although they are not significant predators of sheep. Of 8,339 coyote stomachs analyzed by Sperry (1941), only 3.63% of the total volume contained big game, and of this over 90% was deer, a trace being bighorn sheep.

Coyotes, although the most common large carnivore on the Rock Creek winter range, are less plentiful than they were (at least prior to 1965) due to several intensive coyote control programs. A government trapper set "coyote getter" cyanide bombs on the Brewer-Boomer property at the request of Mr. Brewer following the domestic sheep die-off in the spring of 1965. Mr. Brewer attributes his loss of about 100 sheep (about 75% lambs) to coyote predation. The control area amounted to about 1,000 acres, and the control program netted six coyotes. Since that time, Mr. Brewer has maintained strychnine-poisoned meat at stations on various portions of his property, particularly near his water development.

I have seen seven coyotes and have found four coyote skulls on the winter range. Coyotes can occasionally be heard at night from our cabin adjacent to the winter range.

Two mature female deer were killed by coyotes one-half mile east of the Neal home. These kills occurred in crusted snow during severe weather early in the winter of 1967-68. A female deer found at the mouth of Sheep Creek was evidently killed by coyotes in early February. The animal was in fair-to-good condition and showed no evident physical defects. Two other deer found near Capron Creek during the winter of 1966-67 also were possible victims of coyote predation.

However, no instances of coyote predation on bighorn sheep were recorded during the course of this study. I observed bighorn sheep grazing within 30 yards of a coyote at exclosure site 3. No response to the coyote by the sheep was evident. The sheep were within 150 yards of the rocky outcrops and cliffs below the exclosure.

The high density of deer occupying the winter range may present an effective buffer to coyote predation of bighorn sheep, if, indeed, any such predation would occur.

The mountain lion can be an effective predator of bighorn sheep (Smith, 1954:77; Moser, 1962:34; Couey, 1950). Four bighorn sheep were killed in five days on a Colorado range by a lion (Moser, 1962:34). However, Hornocker (1967) found only two instances of cougar predation on bighorn sheep in three years of study in Idaho, on a range which appeared to sustain near maximum densities of mountain lions and bighorn sheep. The mountain lion was probably once much more plentiful on Rock Creek than it is now. Harold Wyman's barn contains four cougar hides and several cougar skulls. No evidence of the presence of mountain lions was noted during the winter of 1966-67 by residents or researchers. During the winter of 1967-68, one sighting of a lion was reported in the vicinity of Jimmy Leaf mountain in early January (Parfitt and Jarvies, pers. comm.), and I saw three sets of lion tracks within a mile of the winter range adjacent to Willow Creek. Parfitt and Jarvies report that the single lion would stalk the bighorn sheep which, aware of its presence, would interrupt their grazing and run off. This sequence of events occurred several times (sic) before the lion gave up and left.

Although instances of eagle predation on bighorn sheep have been reported (Kennedy, 1947), they are rare. From her home, Matilda Wyman observed an encounter between a golden eagle and a mature ram. The eagle dove at the ram feeding in the grassland at exclosure site 3. The ram reared up on his hind feet, pawing at the bird. When the eagle came out of its dive, the ram ran toward the stringer of timber capping the ridge above him. After several attacks, the ram gained the trees and the bird departed.

During the winter of 1966-67, Aderhold and I regularly saw two or three bald eagles and about six golden eagles. During the winter of 1967-68 only one bald eagle and three golden eagles were observed. The strychnine baits may be responsible for this decline. No instances of predation were noted.

Other occupants of sheep habitat capable of injuring or killing sheep are ravens, foxes, black bear, porcupines, and man. All are relatively harmless except the last.

In sum, although a minimal amount of predation probably occurs, it is insignificant in controlling the bighorn sheep of Rock Creek under present conditions.

Poaching

The bighorn sheep of Rock Creek are quite vulnerable to poaching during the winter months. They can be seen and shot from the road in many areas of the winter range. It is during the bottleneck or low point of the population cycles that the last bighorn of a population can be shot (Murie, *in* Buechner, 1960:156).

During the course of this study there have been many reports of bighorn sheep poaching at Rock Creek. Estimates of Rock Creek residents vary between two and 15 sheep poached each year. The true figure probably lies between these estimates. Field work has yielded two carcasses of illegally shot bighorn sheep in the two years of the study. Of the many reports of poaching, we have tentatively accepted an account of six sheep poached during the mining strike which ran through the hunting season. In this instance, two men from Butte reportedly shot six sheep on two occasions two weeks apart. Another ewe was shot in a foreleg by a deer hunter and presumably perished during the severe weather of the early winter. In the past, participants in the annual censuses have found illegally killed sheep.

If the estimate of four or five sheep poached or mistakenly shot by deer hunters each year is realistic, it would mean a drain of 25-30% on the current (1968) population.

Poaching, which removes about five animals each year, probably had little effect on the population of bighorn sheep prior to the recent decline. At present numbers, the population of bighorn sheep cannot sustain the level of poaching which occurs today. Due to their habits and distribution on the Rock Creek winter range (the bighorn sheep are nearly always found in the open grasslands adjacent to the creek and the road), the sheep are not appreciably harder to find even though there are very few of them. Thus, they are quite vulnerable.

Accidents

The general association and restriction of sheep carcasses to two topographically distinct sites is striking: 1) The bottoms of the gulches leading through the winter range to Rock Creek, and their smaller feeder draws, seemed primarily to harbor the victims of non-immediate mortalities such as disease, malnutrition, and debilitating injuries. 2) The bases of unstable, rugged slopes usually associated with talus, snow slides, and falling rock, contained about 25% of our field finds. They apparently represent sheep which died by falling. It is, of course, possible that predisposing factors, such as poor nutritional status, are the primary causes of such accidents. I have seen sheep attempt to jump to a rock ledge, not make it, trip, and scramble about before regaining their balance. Mr. Robert Neal observed a lamb fall to its death several years ago on the winter range. Smith (1954:83) reviews accidental deaths in the bighorn sheep he studied and concludes that they are a common source of loss.

Inbreeding

The effect of inbreeding on the many small, isolated herds of bighorn sheep has often been privately questioned, particularly by those in the livestock industry, but never studied. The Rock Creek bighorn sheep population has declined to about ten and 25 head in 1915-1918 and 1930, respectively (Part II: Population Dynamics). If rams wander widely, inbreeding may not, in fact, occur in most bighorn populations. Bighorn sheep are, however, unlikely to travel long distances through dense forests to contact other isolated bands of sheep, or to establish new ranges (Geist, 1967). If new blood does not enter the herd, the duration of isolation would be a key factor in determining the extent of inbreeding.

The mutation and recombination of genes leads to genotypic variation upon which selective pressures operate to bring about adaptation and evolution. Mutations are nearly always detrimental because organisms are generally adapted to the environment in which they live. Random mutations are nearly always recessive in an allele, becoming evident only in homozygous offspring with heterozygous parents, each of which bears a recessive gene for a particular trait. Thus, unfavorable recessives do not tend to become evident until their frequency becomes high enough for homozygotes to appear. In large populations in which mating occurs at random, homozygosity is rare.

The general effect of inbreeding in small populations, on the other hand, is to increase the homozygosity of gene pairs. Hutt (1964:380) notes that the most conspicuous results of inbreeding are generally associated with decreased efficiency of reproduction and the appearance of such undesirable traits as a decrease in the number of ova, yield of milk, litter size, viability, growth rate, and vigor.

It is probable that, with intense predation or parasitism, the less vigorous, or the defective sheep would stand much less of a chance than healthy, vigorous sheep of reaching breeding age and thereby perpetuating the effects of increased homozygosity.

A. E. Flower, associate professor of animal science at Montana State University, Bozeman, used an adaptation of Sewall Wright's coefficient of inbreeding to indicate the possible effect of inbreeding in the Rock Creek bighorn sheep population.

Wright's coefficient of inbreeding (Fx) represents the increase of inbreeding in a population per generation. It is the sum of 1/8 of the breeding males and 1/8 of the breeding females present in the population, particularly at its bottleneck, or point of lowest numbers. At present numbers, I will assume that two (the most dominant) males and four females constitute the breeding animals of the population.

Wright's coefficient of inbreeding for Rock Creek bighorn sheep, 1968

$$\begin{aligned} Fx &= (1/8)\left(\frac{1}{M}\right) + (1/8)\left(\frac{1}{F}\right) \\ &= (1/8)\ (1/2) + (1/8)\ (1/4) \\ &= .061 + .031 = .092 \end{aligned}$$

or 9.2% increased inbreeding/generation

This is 9.2% above the initial population inbreeding which is virtually zero for the numbers of sheep prior to the die-off. There is usually a linear relationship between inbreeding and vigor reduction. The effect of each bottleneck is additive. In such small populations these genetic changes do not necessarily respond to environmental alterations through adaptation via the pool of recessive mutations found in a large population. This per cent of inbreeding actually represents a decrease in the heterozygosity of the bottleneck generation of the population.

The effect of inbreeding at the population bottlenecks would tend to decrease the longer the population recovered in numbers because of adaptation through mutations and recombinations. Therefore, the amplitude and frequency of the population oscillations are important. Flower notes that one probably would not see the effects of inbreeding until the 10-15% of inbreeding level is reached. If the per cent of inbreeding is additive and the Rock Creek sheep have declined three times to 10, 25, and now 15 sheep, the inbreeding would be at about the 25-30% level. Although these levels are frequently encountered in manipulations of domestic livestock to enhance desirable characters, "any animal breeder using it [inbreeding] for that purpose should be continuously on guard against reproducing from animals that are lacking in vigor (Hutt, 1964:381)"--something which is difficult to accomplish with wild animals.

Distinctive morphological features can result from inbreeding. It is often possible to identify the locale from which a bighorn trophy was taken by inspection of its horn size, shape, and tightness of curl characters which are presumably, in part, under genetic control. Table 11 and Fig. 4 (Part V: Nutrition, Condition, and Growth) show the quantitative differences in horn characteristics of sheep from Rock Creek compared to those from Wildhorse Island and the National Bison Range. The differences in skeletal measurements of the Rock Creek bighorn sheep compared with other populations of *Ovis canadensis canadensis* indicate that the Rock Creek population is different at the subspecific level (Figs. 5, 6, 7, and 8). The Rock Creek sheep show greater morphological divergence from *Ovis canadensis canadensis* than Cowan (1940) has shown for other recognized subspecies such as *nelsoni*. These differences are based upon the standard taxonomic test of a coefficient of difference greater than 1.28 for a selected morphological character (Mayr, *et al*., 1953:146) and are shown in Table 12.

Although inbreeding seems a probable cause of the smaller size of the Rock Creek bighorn sheep, other possible causative factors exist. These include chronic nutritional deficiencies to which the sheep may have adapted by a decreased size, or short term nutritional deficiencies resulting in growth retardation (Part V: Nutrition, Condition, and Growth). It is possible that inbreeding and nutritional deficiencies have worked in concert to produce the smaller bighorn sheep which are found at Rock Creek.

In sum, it seems that inbreeding probably does occur to a significant extent in the Rock Creek bighorn sheep, with morphological and, possibly, physiological effects.

Table 12. Measurements and coefficients of difference of four skull bones from Glacier Park (Cowan, 1940), Wildhorse Island, and the National Bison Range bighorn sheep compared with the Rock Creek bighorn sheep*

	Sex	Age Group	Locale	Sample Size	Basilar Length	Post-dental Length	Zygo-matic Width	Jaw Length	
	♂	Adults	Glacier	12					
$\bar{X}$					283	99	134		
S. D.					6.82	4.77	4.66		
C. D.					3.08	1.99	0.64		
Mean C. D. All measurements									1.90
	♂	33 mo-6 yr	Bison Range	9-11					
$\bar{X}$					285.7	102.0	137.2	193.9	
S. D.					2.34	1.82	1.17	1.77	
C. D.					10.13	3.7	1.89	6.73	
Mean C. D. All measurements									5.61
	♂	4-5	Rock Creek	2					
$\bar{X}$					262.0	87.8	129.0	170.8	
S. D.					0.0	0.86	3.16	1.66	
	♀	Adults	Glacier	9					
$\bar{X}$					252	87	120		
S. D.					6.27	4.0	2.26		
C. D. (with Rock Creek)					1.45	1.10	0.90		
Mean C. D. All measurements									1.15
	♀	3½+	WHI	2-4					
$\bar{X}$					250.0	88.2	116.7	176.7	
S. D.					5.00	1.04	3.12	10.29	
C. D.					1.42	2.36	0.10	1.29	
Mean C. C. All measurements									1.29

Table 12. (continued)

	♀	3+	Rock Creek	7-13				
$\bar{X}$					239.2	79.9	116.2	161.4
S. D.					2.58	2.48	1.96	1.58

*Details of specific measurements for each animal are given in Table 42.

PART III: BEHAVIOR

Methods and Literature

General treatments of daily routine, seasonal movements, intraspecific relationships, and breeding behavior are given by Honess and Frost (1942), Couey (1950), Smith (1954), and Moser (1962). Moser and Pillmore (1957:18-26) give detailed accounts of the activities of 17 Colorado bighorn sheep (nine ewes, six lambs, a three-year- and a four-year-old ram) observed for three days in early February. Simmons (1962) in Colorado studied the daily and seasonal movements of the introduced Poudre River bighorn population. Forrester and Hoffman (1963) described the growth and behavior of a lamb captured on Wildhorse Island in the spring of 1959. The most intensive study of mountain sheep behavior was based upon nearly four years of field work conducted by Valerius Geist in Canada (1966).

Frequent encounters and observations of the Rock Creek bighorn sheep during the course of the field work yielded much of the data presented below. Many observations were made from the road with the aid of spotting scopes. Others were recorded during attempts to mobilize sheep throughout the winter of 1967-68. In addition, descriptions of the movements and distribution of the Rock Creek sheep have been distilled from the reports of persons interviewed during the course of the study.

Seasonal Movements

Lambing occurs during the latter half of May and in early June. Mr. Robert Neal (*pers. comm.*) observed the birth of twin bighorn lambs on 1 May 1959 in the rocks above the Sheep Creek bridge. By the first week in June, 1967, most of the sheep had departed for the summer range although the general exodus appears to have begun about the first of May. Most of the females drifted north between the first week of May and the first week of June just prior to lambing. This drift is apparently not the usual one, since those people living or vacationing in the area for many years think that most lambing had, in previous years, occurred on the cliffs of the winter range. On the other hand, it is possible that many ewes which had formerly lambed on the cliffs had died during the recent heavy losses, leaving only females which normally lamb en route to, or on, the summer range.

Not all of the sheep left the winter range at the beginning of the summer. Throughout the summer of 1967, two adult females, a female lamb, a male lamb, and a yearling ram occupied the grassy part adjacent to the cliffs on section 16. A lone adult female summered above the rock outcrop overlooking Rock Creek just south of Flat Gulch. During the last week of May and the first two weeks of June, two ewes, one yearling ram, and one lamb of the previous year were frequently seen in the vicinity of a mineral lick in the point of trees above exclosure number 3. A different pair of rams was seen at each extreme of the winter range during the end of June. From these sightings I have estimated that approximately 20% of the population resided on or near the winter range throughout the year of 1967.

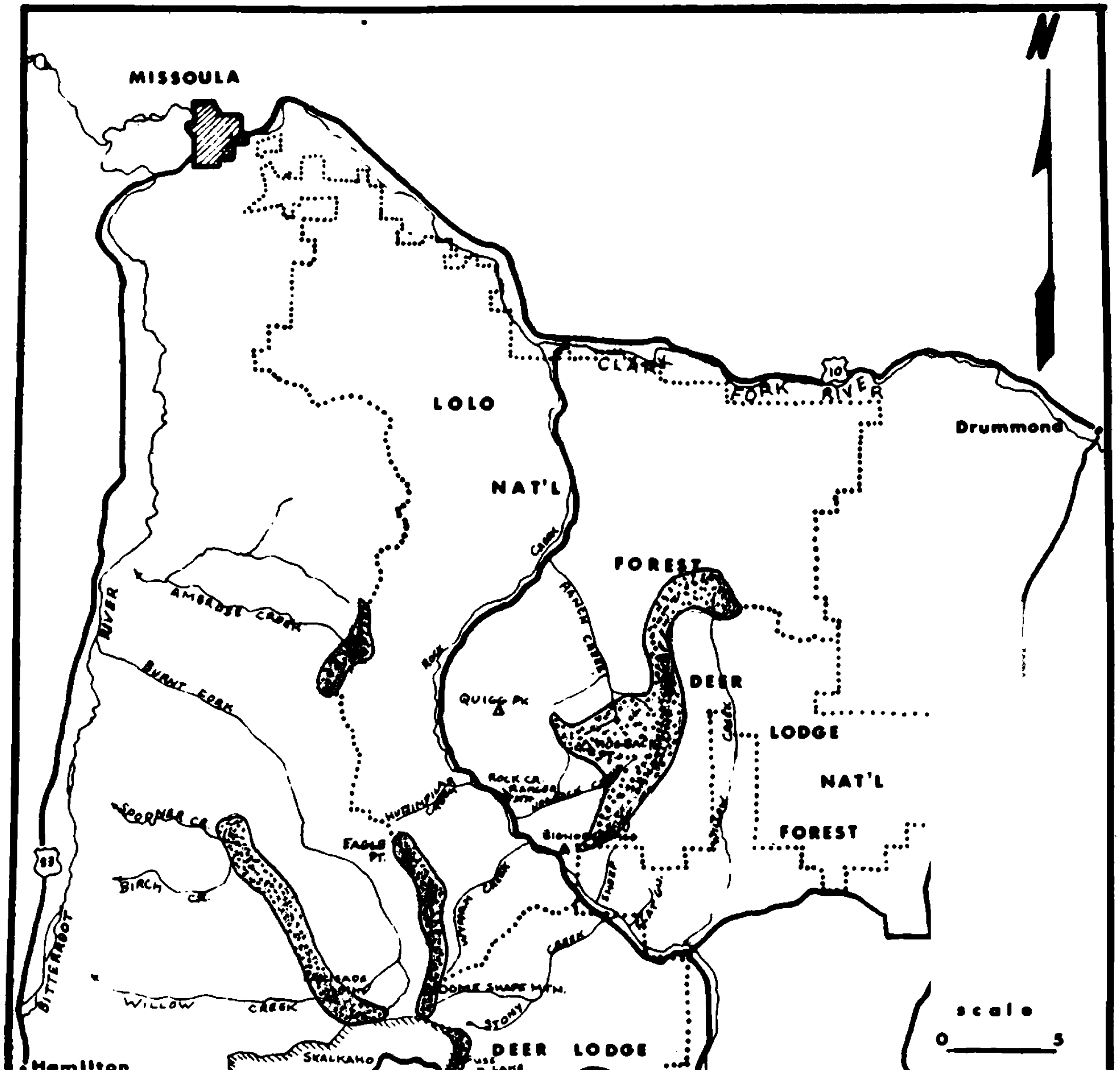
Six of the resident sheep of the summer of 1967 are evidently back this summer (1968) in addition to two new lambs and two other adults. In other words, most of the total winter population now consists of year-round residents. None of the six resident sheep died during the past year, whereas most of the rest of the population failed to return. The two new adults found summering on the winter range may be strays attracted by the resident group. Their gregariousness may be stronger than their former habit of seasonal movement, in light of the apparent absence of other migratory sheep.

The areas in which bighorn sheep have been reported during the summer are presented in Fig. 9. These are tabulated below according to number of animals and source of information.

Table 13. Summer bighorn sheep sightings in the vicinity of Rock Creek

Area	Number of sheep	Period	Source
Dome Shape to Eagle Pk., Palisade Mtn. and headwaters of Willow, Spooner, and Birch Creeks	several, mostly rams	Mid-July - August, yearly	Charles McDonald, U. S. F. S. (former ranger) Stevensville
Fuse Lake	16	Late July 1967	R. Severy, U. S. F. S.
Head of Hogback and above Lower Willow Cr. Dam	approx. 25	July 1967	Helicopter pilot for Bear Cr. Mining Co. survey
Sandstone Ridge	?	Fall 1967	Hunters
Head of Ambrose Cr.	5 dead rams	Prior to study	Harold Knapp, biology teacher
Head of Hogback	?	Prior to study	Miles Rotta, long-time resident of Rock Creek
Dome Shape Mtn.	"many"	Late May 1962	J. Pritze, Johnson Flying Service

Fig. 9. Reported summer ranges of the Rock Creek bighorn sheep.



MISSOULA
LOLO
NAT'L
FOREST
CLARK FORK RIVER
10
Drummond
ROCK CREEK
RANCH CREEK
AMBROSE CREEK
BURNT FORK
RIVER
QUIGG PK.
DEER
LODGE
NAT'L
FOREST
SPOONER CR.
BIRCH CR.
EAGLE PT.
93
BITTERROOT
WILLOW CREEK
STONY
SKALKAHO
DEER LODGE
Hamilton
scale
0
5
N

Ken Price, an employee of the U. S. Forest Service, Bonita Ranger Station, and Archie Spink, who has trapped in the Rock Creek area for about 45 years, report having seen sheep crossing Rock Creek in the vicinity of the Hogback in the summer of 1966, and "in years past," respectively.

From these reports it appears that a portion of the winter sheep population (at least prior to this summer-1968) crossed Rock Creek and summered along the Sapphire Crest, ascending about four miles in the Wyman-Hutsinpilar Creek area. This would involve traversing at least a mile of heavy timber. Another portion of the herd evidently reached the rugged, rocky, talus dissected area at the head of Hogback and Ranch Creeks by following Sandstone Ridge, which rises behind Bighorn Campground. This journey would also involve traversing patches of dense timber. Although Geist (1967) states that "sheep dislike entering timber, and it is thought that wooded valleys act as barriers to dispersion," sheep do cross timber patches and utilize timber as cover during escape. I have seen sheep traverse over a half-mile of heavy timber while escaping. However, sheep apparently do not cross the more extensive tracts of timber. Geist feels that for sheep to cross timber at all, the leader of the band must possess knowledge of the grass range on the other side. This information must have been passed down in the traditions of the herd since the times of continuous grass ranges following the recession of the glaciers.

The return of the sheep in the fall begins in September. We have several reports of sheep seen crossing the Rock Creek road at approximately the extreme north and south ends of the winter range during the latter part of September. The nonresident ewe groups reappear on the winter range during the first week in October. Six ewes and lambs were seen on the road across the creek from Jimmy Leaf mountain on 1 October. They crossed the creek and climbed the hillside.

The mature males are first seen with regularity on the winter range about 1 November. Notes taken by Dr. P. L. Wright, during the first Rock Creek bighorn sheep hunt in 1954, reveal that the rams appeared on 29 October. The first sighting of a mature ram in 1967 was on 9 November. The occasional summer and fall sightings of rams have been noted and could represent a portion of the resident population.

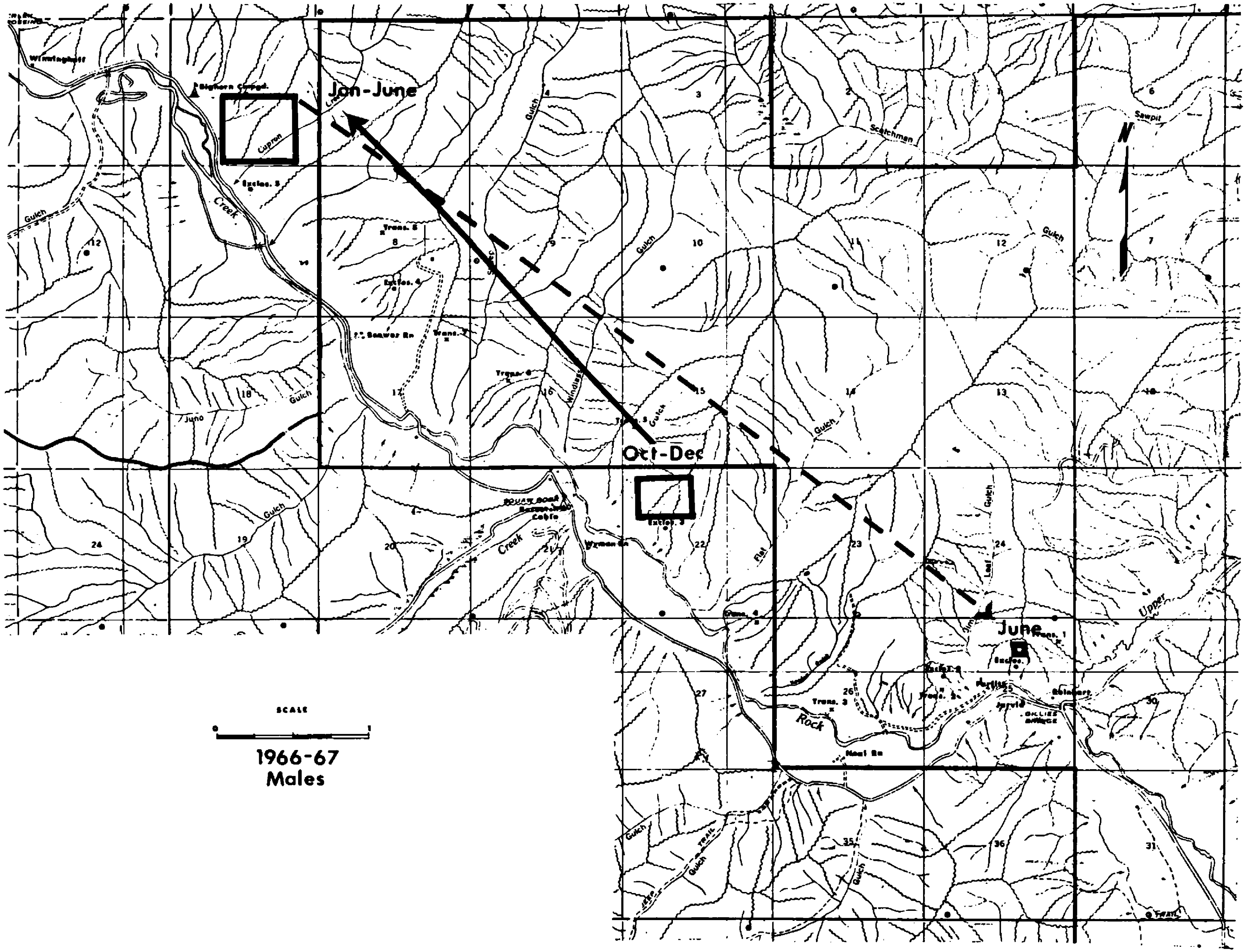
The movements of sheep during the winters of 1966-67 and 1967-68 differed in several details (Figs. 10, 11, 12, and 13). All sexes and age classes were found together throughout the winter of 1967-68. Although some of the sheep occupied Jimmy Leaf mountain upon returning to the winter range in 1967, there was a gradual drift of sheep from the northern portion of the range, with a one-month stopover above the Brewer ranch at exclosure site 4. In late November, coincidental with the early heavy snow, the sheep moved south to exclosure site 3, and after a short stay, moved to Jimmy Leaf mountain at the southern tip of the winter range. In late February the sheep began to wander north again, and sightings between exclosure sites 1 and 3 were common. About the beginning of March, the entire population moved north to exclosure site 3 where they were thereafter sighted with regularity.

During the first week of April in both years of the study, the sheep occupying exclosure site 3 would move down to the chutes and talus fans immediately adjacent to Rock Creek, and graze the emerging green leafage of the bluebunch wheatgrass which appeared on these sites before it appeared elsewhere in the vicinity.

The movement of the entire herd to exclosure site 3 in 1967-68 is in contrast to that of the previous year when half of the sheep occupying Jimmy Leaf Mountain merely shifted their activities from the south to the southeast aspect of the hill with the coming of spring. The other half did move north to exclosure site 3. These movements from one area to another are difficult to explain. The use by sheep of the open, exposed, southeast slope of Jimmy Leaf Mountain during the spring of 1967 was likely due to the early green-up of grasses on this site. The question arises as to why this shift from mid-winter to early spring use was not seen again in the spring of 1968 when the entire band which had occupied Jimmy Leaf Mountain during mid-winter moved to exclosure site 3. The harassment of sheep by the Parfitt's dog (Part II: Population Dynamics) was a factor present in 1968 but not the year before. Also, a portion of the sheep had moved to exclosure site 3 in 1967. Given the low numbers and gregarious nature of the Rock Creek bighorns in 1968, any definite movement on the part of some sheep may have been taken up by others just to stay together.

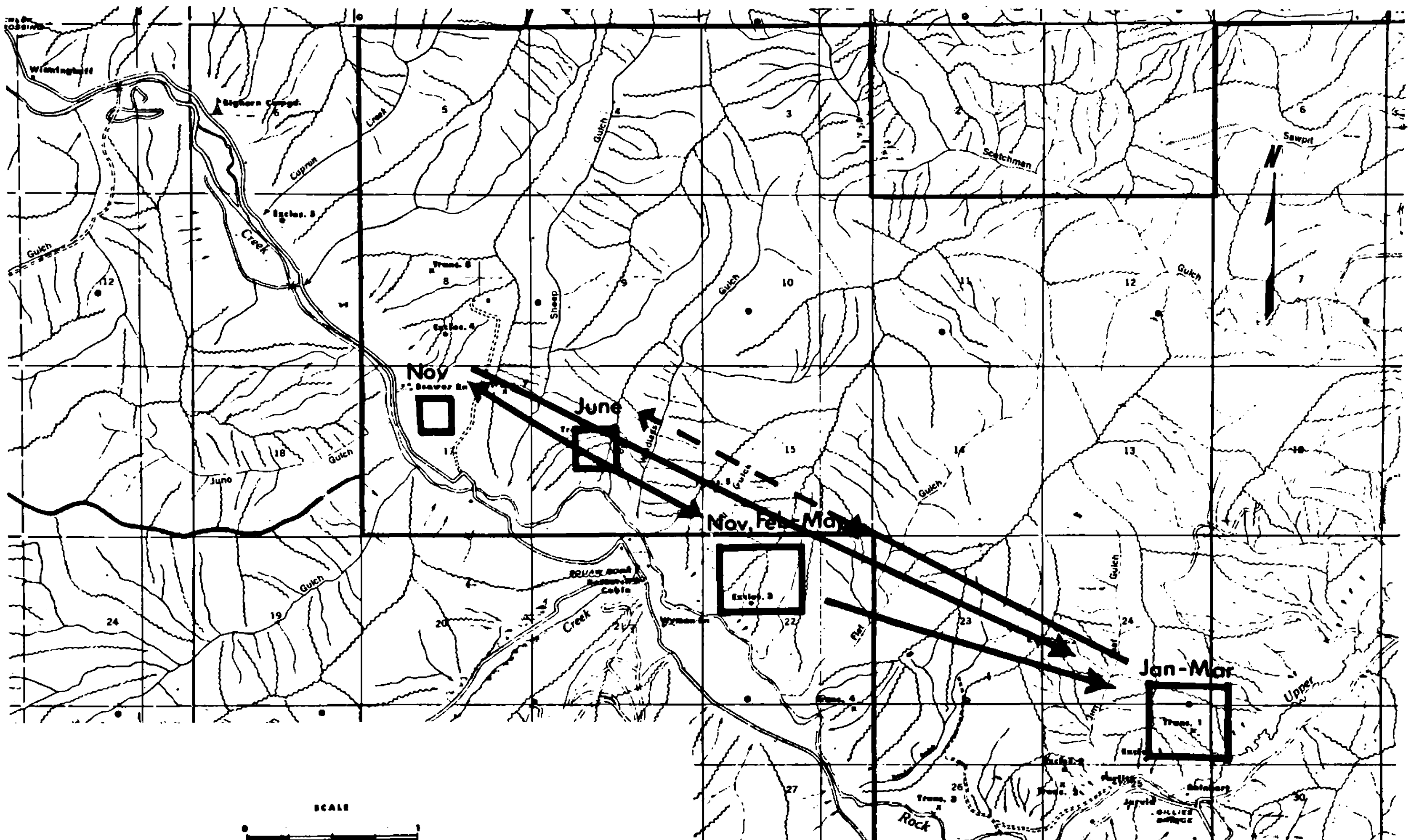
Another unusual feature of the winter movements of 1967-68 was the total absence of sheep from the Capron Creek area where Dr. Wright had noted so many sheep in 1954 and where the mature rams wintered during 1966-67 (Figs. 12 and 14). The older three-quarter-curl male did not return in the fall of 1967. As there were about as many half-curl males as the previous year, it is conjectured that the loss of this patriarch upset the social structure of the males. Geist (1968) describes

Fig. 10. Movements of males on the winter range, 1966-67.



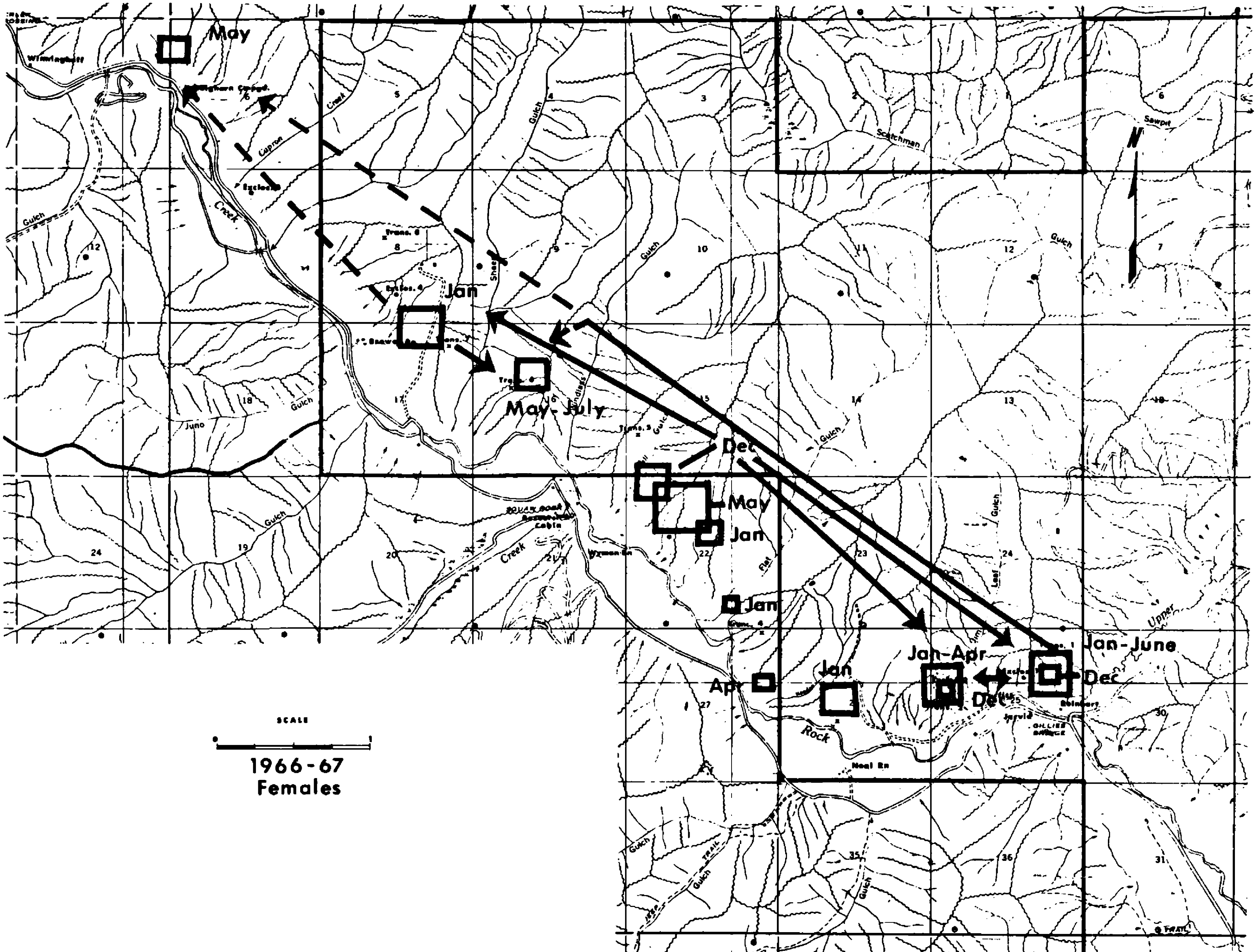
1966-67
Males

Fig. 11. Movements of males on the winter range, 1967-68.



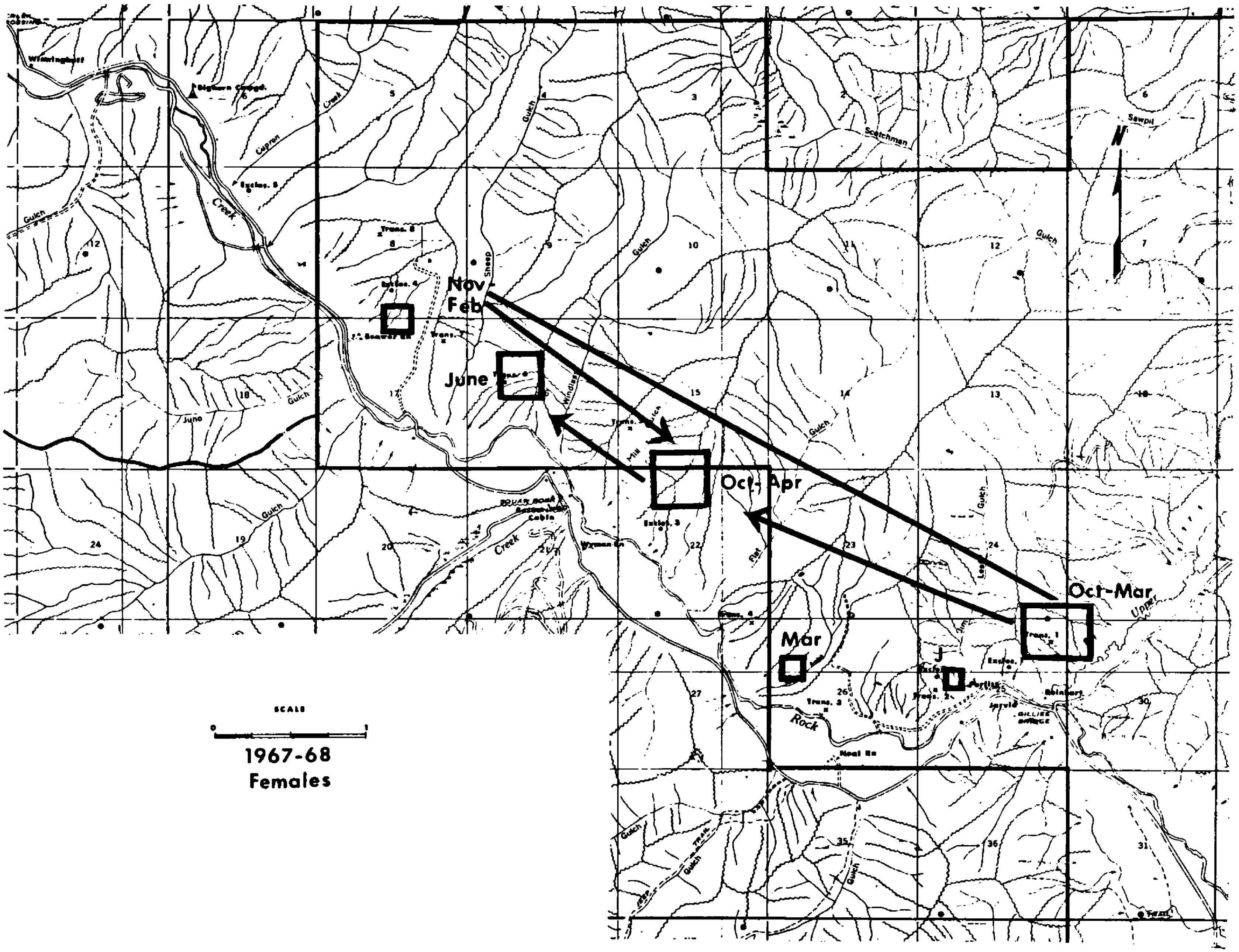
1967-68
Males

Fig. 12. Movements of females on the winter range, 1966-67.



1966-67
Females

Fig. 13. Movement of females on the winter range, 1967-68.



1967-68
Females

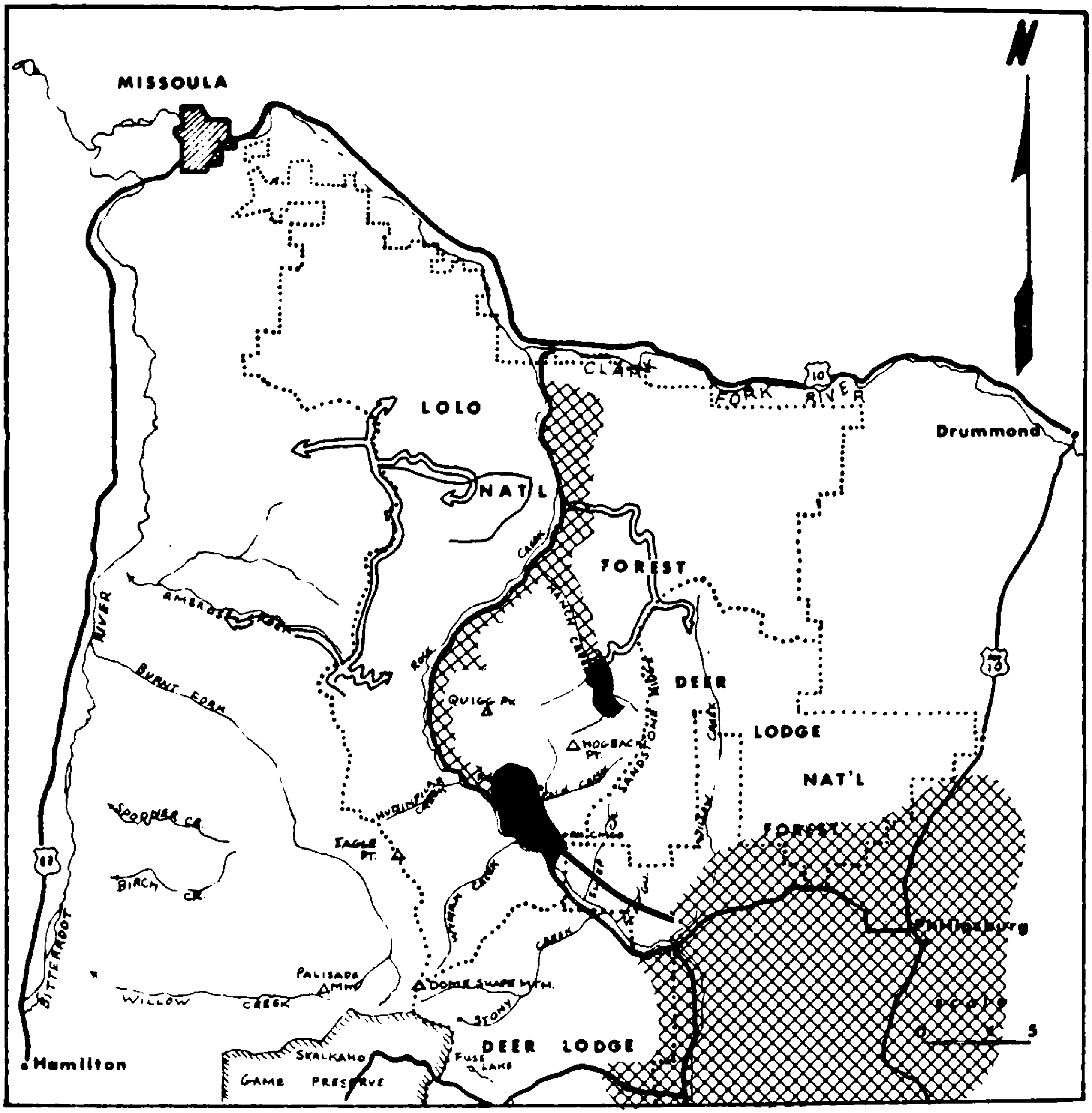
the importance of body and horn size in determining the dominance hierarchy of the sexually dimorphic bighorn sheep. The size dominated hierarchial structuring of the bachelor and ewe groups respectively have been documented by Geist (1968) and are evident to the observer. With the removal of this important figure in the male band, the two-to-four year-old rams lived the entire winter with the ewe bands, although usually preferring the company of another male of similar size to an intimate association with nursery bands during the daytime bedding periods.

Sheep migrations have presumably been greatly restricted over the past centuries, first by the spread of forest into grassland, and more recently by man's cultural practices, along with the extirpation of some local populations. Honess and Frost (1942:6) describe former migrations of up to 60 miles in the bighorn sheep which summered in the Absarokas of Wyoming and wintered in the badlands of the Bighorn Basin. Today, migrations are usually limited to short movements, often within contiguous summer and winter ranges. Blood (1963) found that most of the California bighorn population of the Ashnola region of British Columbia move only two to five miles between summer and winter ranges with some rams migrating up to 15 miles. Sugden (1961) found both migratory and nonmigratory bighorns of the Chilcotin region of British Columbia, depending upon the distance and availability of alpine summer range. Couey (1950:28) records migrations of about ten miles for the Sun River bighorn sheep.

With the elimination or decrease in the proportion of sheep dispersing from the winter to the summer ranges, increasing numbers of sheep will be foraging upon an already overtaxed forage resource, particularly during the season of plant growth, if the present population recovers from the current low level. Also, the concentration of sheep throughout the year in a restricted area would increase the effect of density dependent decimating factors. The winter range would not be able to support the same numbers of sheep as it had in previous years, and a decline of the original population would result. The loss of sheep in isolated portions of the winter range would result in the permanent loss of these ranges, assuming that traditions once lost are permanently deleted from the behavioral repertoire. Evidently this loss of former range has occurred on Rock Creek as Fig. 14 showing a reconstruction of the winter distribution of bighorn sheep illustrates. This reconstruction is based primarily on the ranges given by Couey (1950:5) and interviews with residents.

The movements of each class of sheep wintering on Rock Creek are detailed in Figs. 10, 11, 12, and 13. There are definite, repeatable patterns of movement throughout the occupation of the winter range by the entire population of sheep: 1) In October and November the sheep occupy the northern portions of the winter range, including the area between Bighorn Campground and Windlass Gulch. 2) In November and December they move to the middle of the winter range at exclosure site 3 followed by a January movement of females to Jimmy Leaf hill and males to the other extreme of the range at Capron Creek where they remain until early spring. (At the higher population levels found in the winter of 1966-67, smaller groups of females could be found at a few other sites on the winter range, such as exclosure site 4.)

Fig. 14. Original winter distribution of bighorn sheep in the Rock Creek region.



Present winter range

Reported winter range (1920-30) in addition to present range

Reconstruction of original bighorn winter range

3) A movement to a salt lick and green forage at exclosure 3 begins in March. Some sheep were still seen in June when most of the sheep had departed for the summer ranges. 4) A later spring movement to summer ranges occurs primarily in May, the route of the sheep taking some of them at least as far north as the Winninghoff cabin (Fig. 3). 5) Six to ten sheep summer on section 16, breaking off from the northerly spring movement.

Behavior of Individual Flocks

Density and Spacing

The density of the bighorn sheep during the winter at Rock Creek approached 115 per square mile at maximum numbers and nine per square mile at the low population level of last winter. In the home range areas (which here include daily feeding, bedding, and escape terrain) of the past two winters, the density of sheep was about 64 per square mile.

The range is occupied by four distinct bands of sheep, each separated from its neighbors by about two miles: 1) One band occupies exclosure sites 1 and 2 on either side of Jimmy Leaf Gulch. The home range of the nine sheep wintering on Jimmy Leaf Mountain, based upon 34 observations of sheep groups and continuous surveillance for three complete days and periodic checks throughout the winter, was 800 yards long by 450 yards wide, or 0.35 square miles. 2) A second band occupies exclosure site 3 with the same size home range area as found on Jimmy Leaf Mountain. 3) A third band occupies exclosure site 4. 4) The ram band occupied exclosure site 5. The Capron Creek home range of the four rams during the winter of 1966-67 was nearly twice as large as that of these mixed groups of one year later described above. With the reduction in numbers, all exclosure sites were used during different periods during the occupancy of the winter range with the exception of exclosure site 5 which was abandoned during the winter of 1967-68.

Simmons in Colorado (1962) found a nearly identical daily cruising radius as that of the Rock Creek sheep--832 yards. Skinner (In Leopold, 1933) gave a daily cruising radius of 110 yards for bighorn sheep in Yellowstone.

Group Size

One hundred eighty-two observations of bighorn sheep groups were made between December 1966 and July 1967 and between October 1967 and May 1968. The average group size was 3.4 animals (range: 1-20) with little difference between the average group sizes of each field season. Motion pictures taken by Harold Wyman (about 1957) show 72 sheep forming up in response to some disturbance. Because of this tendency to coalesce when disturbed, I have omitted the data on group size gathered during each annual census. Table 14 summarizes group size by year and class of sheep.

These figures tend to mask the existence of the discrete bands. For example, nine sheep could be found in two general groups of four and five animals each on Jimmy Leaf Mountain through most of the winter. However, often only two or three could be seen at any one time. After moving to exclosure site 3 at the beginning of the spring of 1968, these nine sheep joined three others. The 12 sheep were together when field work terminated in the spring.

Table 14. Average group size of Rock Creek bighorn sheep by sex, based upon 182 observations[1/]

Year	All ♂♂	All ♀♀	1 and 2 yr. ♂♂	Breeding[2/]	All groups	All groups excluding singles
1966-67	2.1(1-4)	3.1(1-10)	1.0		3.2(1-20)	
1967-68	[3/]	3.0	1.0		3.6(1-5)	
Total				3.9(1-20)	3.4	4.2

[1/] Range in parentheses.
[2/] December 1966-January 1967, October 1967-January 1968.
[3/] Only once during this year was an adult male seen without nearby females.

The members of a group would gather for any movement, traveling a loose single file to salt, forage, and cover.

The above table indicates the relative size of the different classes of sheep groupings. The males were often seen singly or in pairs during the breeding season, four of the males returning in a bachelor band to the Capron Creek wintering grounds. The female-yearling-lamb groups were larger than male groups and more stable. Yearling and two-year-old males were the most solitary. Males and females were found together in larger bands during the breeding season.

The difference between my observations of single sheep and those of Smith and Blood (Table 15) reflects the unusual association of ewes and rams during the second winter.

Table 15. Classification by per cent of single sheep seen

	Ad ♂♂	Ad ♀♀	Yearlings	Lambs
Present study	21	45	24	10
Smith (1954)	52	31	18	
Blood (1963)	65	31	4.5	

The fact that the rams did not remain solitary also reflects the relatively youthful structure of the male portion of the population. Older rams will be found alone more often than the younger adult rams. The association of young (three- to four-year-old) rams with female groups through the winter of 1967-68 might represent an interesting reversal of the dominance hierarchy based upon horn and body size established in the presence of the older males (Geist, 1968).

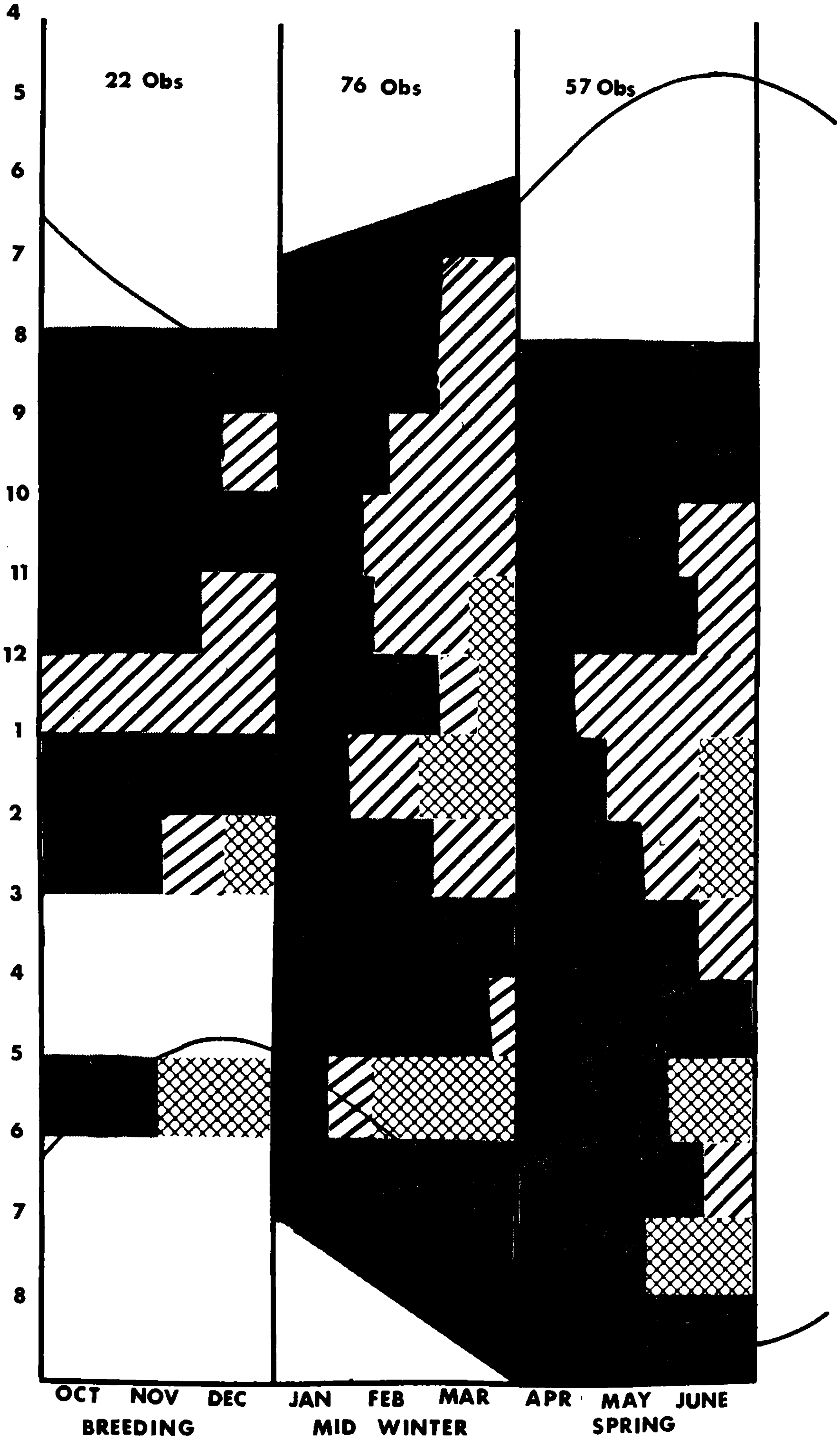
The average group size of the 250 California bighorns Blood (1963) studied was 9.3 sheep. Smith (1954:48) found the average size of groups in his study area to be 7.3 animals. Baillie-Grohman (1882) reported that the average flock in the Rocky Mountain bighorn of 80 years ago was eight animals. From this Smith concluded that flock sizes had not decreased in proportion to the decrease in sheep populations. Our data showing smaller group sizes than found in larger populations would tend to contradict his interpretation or possibly indicate a threshold number or density below which group size is affected. In some other species group size is directly related to abundance. Rausch (1967) found that pack size in wolves decreased with a decrease in the total population.

Diurnal Activity

The bighorn sheep is primarily diurnal (Blood, 1963; Moser and Pillmore, 1957:18-20). Several predictable patterns of daily activity can be distinguished.

Fig. 15 graphically presents the patterns of bedding, feeding, and moving found in the Rock Creek bighorn sheep. These patterns are related to photoperiod by the curved lines showing the time of sunrise

Fig. 15. Diurnal activity of the Rock Creek bighorn sheep, October through June. Solid: feeding; slanted lines: bedded; crosshatch: moving. Times of sunrise and sunset are indicated by relating the curved lines to the ordinate.


22 Obs
76 Obs
57 Obs
4
5
6
7
8
9
10
11
12
1
2
3
4
5
6
7
8
OCT NOV DEC
BREEDING
JAN FEB MAR
MID WINTER
APR MAY JUNE
SPRING

and sunset throughout the period of observation. Observations have been divided into the fall breeding period, mid-winter, and spring. We can see several relationships even in these limited data: 1) the sheep begin feeding immediately after rising from bedding grounds; 2) a low level of resting or bedding is evident between 9 A.M. and 3 P.M., the most pronounced bedding occurring at about 10 A.M. and 12 noon. The investigations of bighorn sheep cited above reveal a mid-morning bedding period of about an hour's duration, and an early afternoon bedding period of about two hours' duration. The Rock Creek sheep graze prior to and after each bedding period. 3) Increased movement (motion at a definitely faster pace than that maintained while grazing) occurs after each bedding or inactive period. The movement which takes place between 5 P.M. and sunset usually brings the sheep to the bedding grounds of the previous night. 4) Sheep are less active during the mid-winter mornings than during either the spring or fall. There is a lengthened period of feeding with an increase in day length. This agrees with the tentative findings of Blood and contradicts Smith (1954:50) who felt that bighorns spent more time foraging in mid-winter than during the other periods of winter range occupancy.

The discontinuity between the different seasons is due to the differences in the number of observations made for each period.

Rarely are all sheep in a band bedded at one time. Usually about half the band would feed while the others rested. Often a sheep would interrupt its grazing to peer intently down and across the hill on which it stood, resuming grazing 2-10 minutes later. Sheep would bed under trees in open timber or, more frequently, right in the middle of the grassland in which they happened to be feeding. The sheep lay with the contour, their feet tucked under and peering downhill while ruminating. Sometimes the sheep would prepare a bed by scraping the ground with a front foot.

The average distance covered while feeding was 6.3 feet per minute and when moving, 25 feet per minute. Sheep would usually graze along the contour, often turning about every 20 yards and returning the same distance several feet above or below their previous path. The tendency was to both turn and graze slightly uphill. The tendency to contour while grazing is shown in Table 16 which details the attitudes of feeding and escape movements.

Table 16. Attitude of local sheep movements on the Rock Creek winter range 1966-68*

	Escape**			Undisturbed feeding and moving		
	Up	Down	Horizontal	Up	Down	Horizontal
Contouring	19.0(4)	23.8(5)	23.8(5)	31.6(12)	10.5(4)	44.7(17)
Vertical	9.5(2)	23.8(5)		10.5(4)	2.6(1)	
Total	100(21)			100(38)		

*Discussed in section on interspecific behavior.
**Based on per cent observations--actual numbers in parentheses.

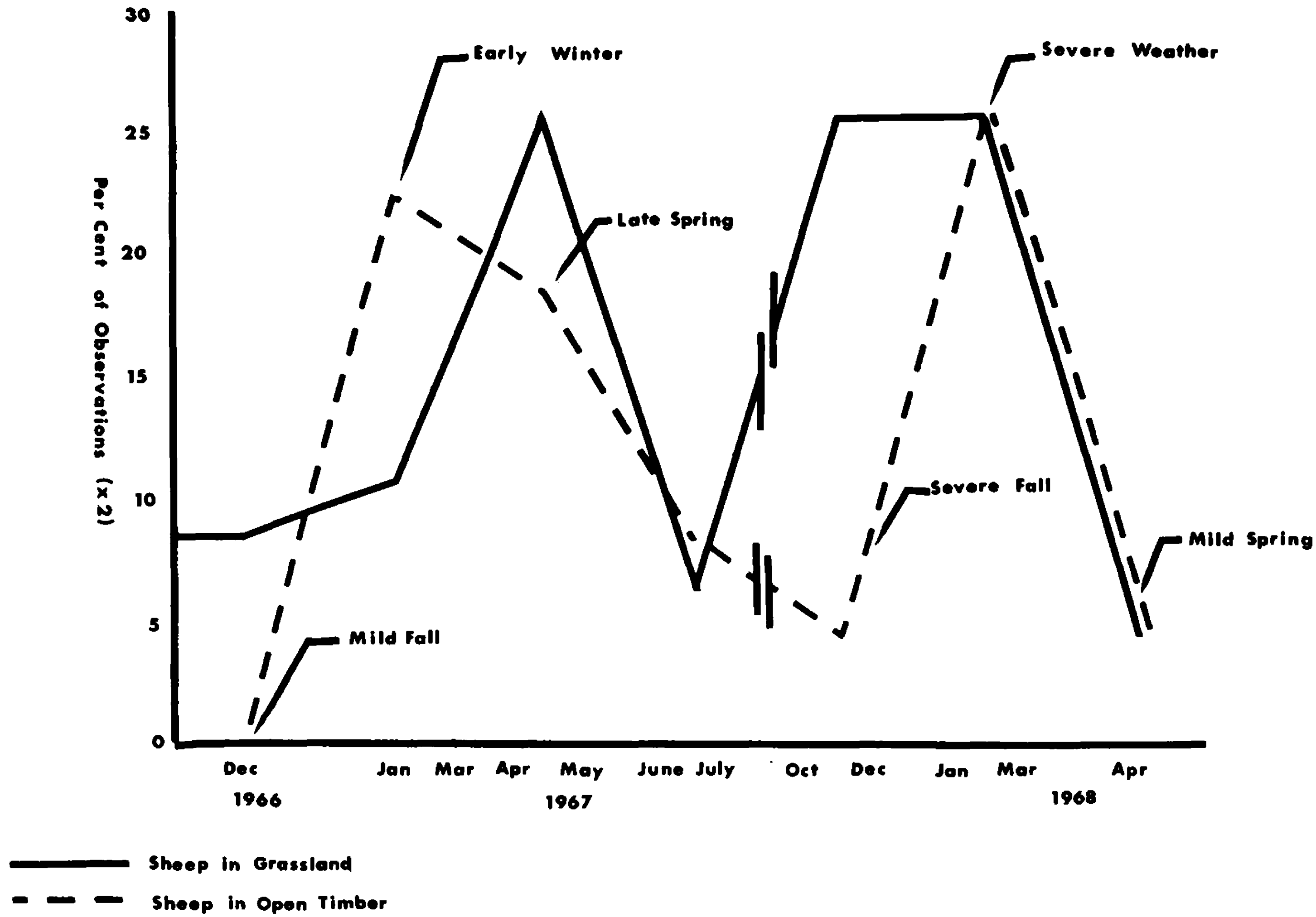
Although the selection of mid-day beds primarily depended upon where the sheep happened to be feeding (beds were different on different days), the nightly bedding grounds were invariably rocky areas, usually with a rear protected by rock outcrops, extensive view, and associated with open, scrubby timber. There were approximately two such areas on each home range, and one or the other was used each night. There was always an escape route such as a chute or ledge.

The sheep were much less observable during periods of inclement weather. They would occupy areas similar to those described for the nightly bedding grounds. When considerable snow had accumulated, the sheep would usually be found in the open timber types utilizing the protection afforded by the canopy of conifers for bedding and feeding areas. Couey (1950:34) relates the use of caves by sheep during periods of inclement weather. My summer observations indicate the use of the open timber type, possibly for relief from the heat, although the open grasslands were utilized for feeding even during days with temperatures in excess of 90° F. Cowan (1940) notes the tolerance of sheep as a genus to a high range in temperatures (from about -60° F. to 120° F.) Fig. 16 illustrates the tendency to occupy open timber types during periods of inclement weather. The line representing observations of sheep in the grassland type is an index of the abundance of sheep rather than the per cent time spent in the grassland. The sheep are much more readily observed in the open grassland. Attention should be directed to the relative changes in use of the timber type in proportion to the severity of climatic conditions. The difference between the relative occupancy of the open timber type between the mid-winter periods of 1966-67 and 1967-68 is emphasized by the smaller number of sheep using the winter range during the winter of 1967-68. Use of the open timber type increased by about 20% during 1967-68.

Interactions

The sheep fed in a rough line with an older female at either end of the line. This was true in nursery bands or mixed male and female

Fig. 16. Occupancy of grassland and open timber habitat types related to climate.


30
25
20
15
10
5
0
Per Cent of Observations (x 2)
Early Winter
Severe Weather
Late Spring
Severe Fall
Mild Spring
Mild Fall
Dec
Jan
Mar
Apr
May
June
July
Oct
Dec
Jan
Mar
Apr
1966
1967
1968
Sheep in Grassland
Sheep in Open Timber

groups. Lambs and yearlings appeared to be the most nervous or alert while feeding in nursery bands. In mixed male and female groups, ewes were much more alert than the males.

The distance between undisturbed grazing sheep of a flock averaged 27.5 feet (range: 1-450).

Few intraspecific interactions were observed. The most common interaction was a butting of the smaller animals, usually lambs, by ewes. The young animal would respond with a jump, trot about ten yards, and resume grazing. Butting and horn threats are common in bighorn sheep and are classified by Geist (1968) as aggression patterns. Lambs were observed playing a form of "tag" during December of 1966 and April of 1968. This consisted of running at each other, occasionally jumping into the air. At both times, forage conditions were good, and there was no snow cover.

On two occasions during the late winter of 1967-68, solitary yearling males stood upon a promontory bleating for several minutes. This was the only form of vocalization noticed.

Scratching behind ears, in the neck, and rib cage with a hind foot was very common in sheep of all ages and both sexes, particularly during March. The sheep were seen backing into shrubby junipers and rotating their rear ends for several minutes. Both sexes would stick their faces into junipers and thrash them about. This probably served to relieve irritation by ectoparasites.

Other forms of maintenance behavior include the preparation of beds noted previously and, rarely, coughing during the spring of 1968.

Interspecific Behavior

Magpies (*Pica pica hudsonia*) were frequently seen sitting on the withers, flanks, and heads of grazing or bedded sheep throughout the winter. They would peck in the pelage of the sheep, presumably for ectoparasites. The sheep were tolerant of this activity; I never observed the occasional resentment described by Smith (1954:54). I observed up to three birds on one sheep.

Mule deer were frequently seen grazing close to the bighorn sheep. Groups of up to 17 deer would graze past the sheep at distances of less than five yards. The groups of sheep and deer would always retain their identity; I never observed any extensive intermingling, except in flight. Often an entire band of sheep would stop grazing and peer intently at a nearby group of deer. The sheep appeared to use the deer as watchmen and should the deer take flight, the sheep would also flee, although not always in the same direction. In flight a random intermingling of the two species would occur. On one occasion 30 head of mule deer with a yearling male bighorn sheep in the middle of them ran headlong toward me, stopping upon seeing me at a distance of 20 yards. The deer and the lone bighorn watched me for two minutes, and then the deer slowly filed toward and below me. The young ram continued gazing at me after most of the deer had gone. This incident illustrates the apparently more curious nature of the bighorn sheep.

The reaction of sheep to coyotes and mountain lions and eagles has been noted in the discussion of predation.

The reaction of the Rock Creek bighorn sheep to man has apparently changed since hunting began in 1954. Wright (pers. comm.) believes that the sheep are becoming increasingly wary and nervous in the presence of humans. Certainly the sheep of Rock Creek are much less approachable than those of the Yellowstone, the National Bison Range, or the Many Glacier populations.

The bighorns appeared oblivious to domestic animals sharing their range. Until recent years, their tolerance of horses had allowed Mr. Robert Neal (pers. comm.) to ride into a band of grazing bighorns without disturbing them.

Altmann (1958) has attempted to quantify the flight reactivity of free ranging moose and elk by employing the measurement of the "object flight distance." Some variables which influenced the object flight distance are: seasonal changes in reproductive or nutritional status, variations in the type of habitat, and variation in the experience of the group.

Table 17 gives the average object flight distance in feet of all sheep encountered.

Table 17. Average object flight distance by month of the Rock Creek bighorn sheep and the Shiras moose studied by Altmann (in feet)*

	1966	1967									1968			
	Dec	Jan	Feb	Mar	Apr	May	June	July	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Sheep**	120	150	125	107	130	57	250	300	...	240	...	210	116	50	45
Moose	-------20-60-------					30-70		150-200-200 300		----------20-60-------					

*Altmann's data do not correspond to the year of the Rock Creek data.
**Number of observations was 92.

There appears to be a decrease in the object flight distance coinciding with the low point of physical condition in the early spring; the sheep were apparently less sensitive to disturbance. The extreme was a ewe in such poor condition that Aderhold, thinking her dead, walked up to within two feet of her before she jumped to her feet and ran off.

Altmann's flight distance figure of 200-300 feet for hunted moose during September and October represents a ten-fold increase over the flight distance of moose which are not hunted. Altmann thought that a decrease in vigor and increased snow accounted for the lower flight distance during the winter months. As snow was never limiting when data were collected for the Rock Creek sheep, a decrease in vigor is the likely reason for the lowered flight distance of early spring.

The natural curiosity of the bighorn sheep influenced their flight distance. They would occasionally advance toward the observer. Once, after I had been discovered by a ewe at a distance of 100 feet, she watched me intently for two hours while two ewes, a yearling, and a lamb continued grazing by her side. During this study, a stamping of feet, scent or flight itself seemed to be the only means of communicating danger between bighorn sheep, and without these signals the other sheep remained completely unaware of my presence. In this case, I was shielded by a juniper tree from two of the sheep and when I arose, the three sheep, seeing me, fled while the other two sheep, trusting to their senses, remained. This episode emphasized the importance for bighorns of visual contact with the object of disturbance. After three minutes, the three sheep, which had seen me and fled, rejoined the lamb and ewe (which may have been the leader of the group). In another case, a yearling male grazed to within ten feet of me until he suddenly started and ran 75 feet into the timber. As I had made no motion or noise, I presume my scent was detected. However, he did not really leave the area until he had visually confirmed my presence.

The direction and extent of flight depends upon: 1) the limitations of the terrain, and 2) the proximity and intensity of the stimulus. The sheep occupying Jimmy Leaf hill were restricted to a small area of favorable escape terrain. By making several vertical and horizontal movements, the sheep would take advantage of all of the escape terrain, such as rocky outcrops and trees, utilizing the entire hill in flight. In other area, such as exclosure site 3, flight would most often be the straightest line away from the intruder. Escape from people who were moving toward the sheep from some distance was much more leisurely and shorter than flight from people who had surprised the sheep from within 50 yards. During hunting season, deer hunters could be seen pushing bighorn sheep in front of them in this manner until the sheep had attained the cliffs in back of the Wyman ranch.

Sheep which had been surprised at short flight distances would run up to three-quarters of a mile, often crossing a drainage in their escape.

Smith (1954:50) mentions the tendency of sheep to escape toward the nearest high ground, even if this requires running toward the source of disturbance in doing so. We did not notice this trait. However, sheep would not run directly to the cliffs which were always below them but preferred contouring, placing the maximum distance between themselves and the disturbance before going down to the cliffs.

PART IV: VEGETATION AND FORAGE COMPETITION

Literature and Methods

Range analyses were designed to treat six discrete problems: 1) floristic composition, range condition, and trend; 2) edaphic influences on the vegetation; 3) total herbage production; 4) forage utilization; 5) competition for forage; 6) nutritive qualities of the forage (Part V: Nutrition, Condition, and Growth).

Floristic Composition, Range Condition, and Trend

After locating primary areas of bighorn sheep winter use on the grassland type, the problem was to determine why sheep restricted most of their feeding and bedding activities to these key areas. The hypothesis that the range restriction was caused by a reaction to environmental conditions, rather than an enactment of traditional or innate predilections of a band of sheep for a particular area on the winter range, was tested. The most obvious environmental factor which could influence sheep concentrations, namely, the availability and quality of forage, was examined in some detail. Other environmental factors which could influence the distribution of the sheep on the winter range, such as climate, terrain, etc., were examined and are noted elsewhere in this paper.

Areas which appeared to have all of the physiographic habitat elements apparently required by bighorn sheep, such as adequate expanses of bunchgrass range interspersed with broken bluffs and stringers of timber (Honess and Frost, 1942:4, 5; Smith, 1954:38, 59; Blood, 1959:11), but which did not receive appreciable use by bighorn sheep, were inventoried as were areas of moderate and heavy sheep concentration.

Eight transects were run: three (numbers 5, 7, and 8) transects in areas where the sheep were not observed more than once, two (numbers 3 and 4) where the sheep were seen periodically, and three (numbers 1, 2, and 6) where the sheep were seen frequently and which were considered to be key portions of the winter range (Fig. 17).

The transects each consisted of 50 one ft^2 quadrats. Eight transects, totalling 400 square feet of area, were run. The general area to be sampled was selected on the basis of sheep use and then stratified by selecting for uniformity of slope, aspect, soil type, and general floristic composition. The largest "type" so sampled was transect number 3, 80 x 100 yards, the smallest was transect number 4, 40 x 60 yards, and the average type constituted about one acre, 4,840 square yards. The plot frame was thrown into the type to determine the first sample site. Five rows of ten samples each, spaced evenly throughout the type, completed the sampling. The per cent of the plot covered by each plant species, using a modified canopy coverage estimate, was entered on prepared forms (Appendix A). The herbage was gathered so that no ground was visible between the leafage, and the per cent coverage was estimated from the 50, 30, 20, 10 and 2½ per cent wire divisions of the one ft^2 plot.

The transects were run during the last week in June, due to a late spring with snow flurries in May and early June. This was about the peak of flowering of most of the range plants. The transects served as a detailed check on the type-mapping of the winter range which I conducted by ocular reconnaissance during the first two weeks of June. Comparisons of species and density data with old Forest Service type maps (1938) and with Buechner (1960:131) gave estimates of range trend. For the present study, indicator species were classified as increasers, decreasers, or invaders and related to both range condition and sheep distribution.

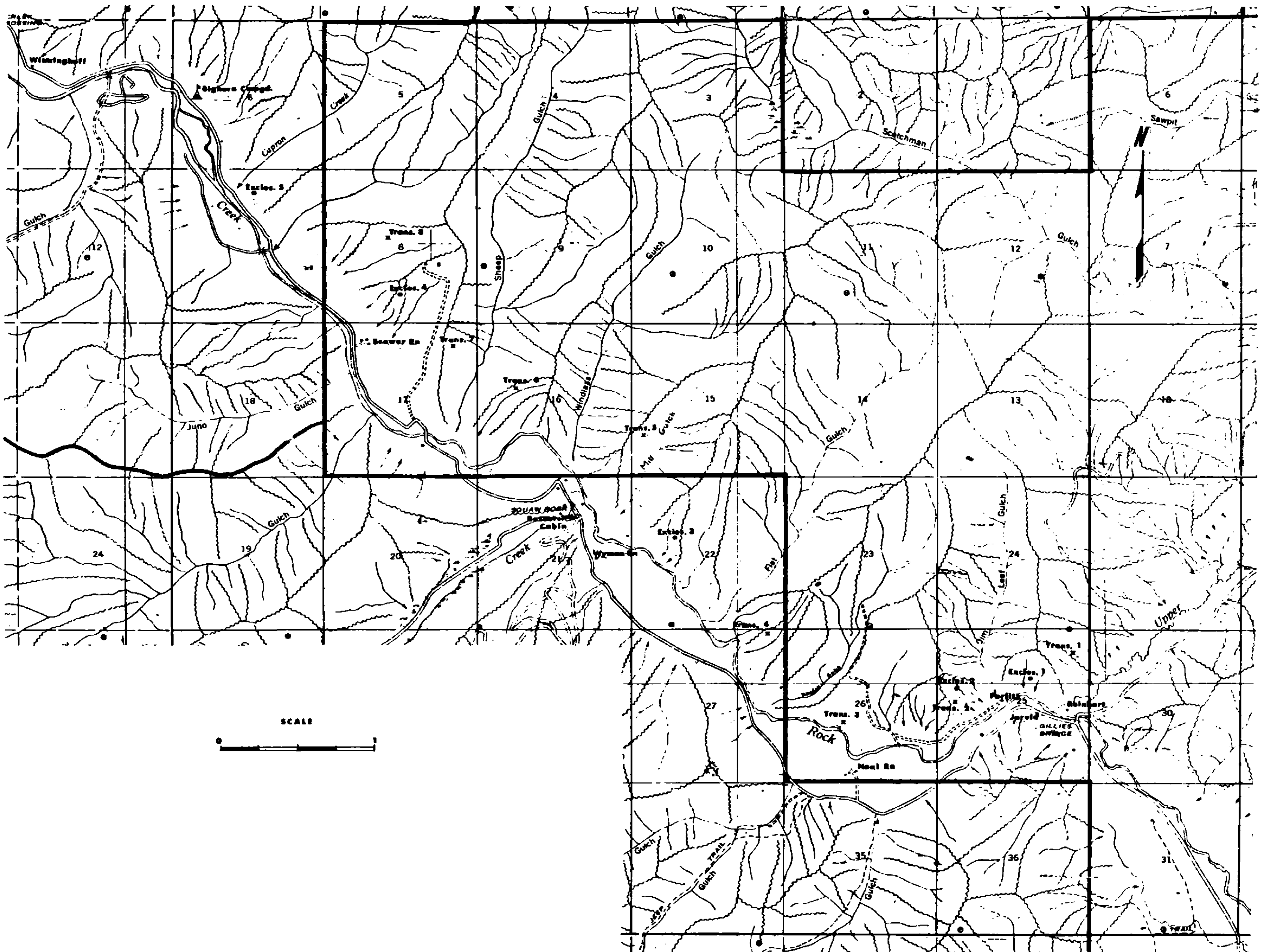
An objective of these studies has been to clarify the degree to which selective grazing has modified the abundance and distribution of the range plants, and therefore the successional status of the site. This plot sampling method is designed to provide an index of the relative abundance of each plant species and to enable comparisons of selected indicator species to be made with other sites or on the same site at different times. Dayton (1931) and Carpenter (1956) define density as the degree to which vegetation covers the ground. Dominance of species and plant competition can be expressed in terms of this foliar projection method (National Academy of Sciences - National Research Council, 1962:49). Also, "species-list quadrats can be used, in a rough way, to determine competitive rank among range plants, providing soil conditions are uniform (NAS-NRC, 1962:30, 31)."

Edaphic Influence on Vegetation

The types of soils found on game ranges are increasingly employed as indices of the wildlife productivity of these ranges (Crawford, 1950). The presence and availability of inorganic nutrients varies with different soils. Mitchell and Hosley (1936) found over a twenty-fold increase in use by deer of forage from nitrogen treated soils compared to untreated plots.

We were fortunate in having access to a recently completed soils survey conducted by the Soil Conservation Service, which included an

Fig. 17. Transect and exclosure points on the study area.



Wimingbuff
Bighorn Cmpgd.
Capron
Creek
Excles. 5
Trans. 8
Excles. 4
Sheep
Gulch
Windlass
Trans. 7
Trans. 6
Mill
Juno
Scotchman
Sawpit
N
Square Rock Cabin
Excles. 3
Flat
Leaf
Trans. 4
Trans. 1
Excles. 1
Excles. 2
Trans. 2
Trans. 3
Rock
Neal Rn
Reinhart
Gillies Bridge
Upper
Trail
SCALE
0
1

indication of the influence these soils would have on vegetative response to varying degrees of use, depletion, and productivity. The soils data is expected to show the limits within which the sites can produce forage of sufficient quality and quantity to support the wildlife on the winter range, the present intensity of domestic use, and also the capacity of the site to respond to treatment.

Total Herbage Production

To measure the total herbage yield of plant species found in the key bighorn winter range areas, clipping studies were conducted at about the time of maximum plant growth in early July.

The five exclosures were constructed during the first two weeks of April before domestic stock had been turned out and before there was any appreciable plant annual growth for game to clip.

Each exclosure was square, 20 feet on a side. Each was constructed of 32 inch woven wire fencing and attached within an inch of the ground. The sheep-tight fence topped by two strands of barbed wire at 12 and 18 inch intervals was 5¼ feet high.

At the height of plant growth (approximately the first week of July in 1967) ten 4.8 ft^2 plots were clipped within each exclosure, using a 1 by 4.8 foot welded pipe frame (Fig. ~~19~~ 18). The ten 4.8 ft^2 plots yielded a computation of production in pounds per acre when weights are multiplied by a factor of two.

Elimination of a two ft area of possible disturbance around the side perimeter of the exclosure left a square sampling area 16 feet on a side. The plot frames, being 1 foot by 4.8 feet, the sampling area was gridded by determining 16 points, one foot apart on one side and 3 points, 5 feet 4 inches apart on the other axis. From a table of random numbers, the following ten plots were selected for clipping (by rows): 1-1, 1-2, 2-3, 4-3, 6-1, 9-1, 9-3, 10-1, 11-2, and 12-1 (Fig. 19).

Plants were clipped at ground level (Fig. 18) and separated by species. The clippings were weighed, oven dried at 105° C. for 24 hours, then reweighed.

Forage Utilization

The clipping studies served to indicate the quantity of forage being produced and then removed by grazing. The difference in weight between randomized plots clipped before (protected from grazing by an exclosure) and after (unprotected and outside of the exclosure) grazing represents the amount of forage utilized (Duncan, 1959:32). Clippings were planned for the summer to indicate total growth, in the fall to indicate domestic use, and in the early spring, before the cattle were turned out again, to indicate game use. Unfortunately the winter of 1967-68 began in mid-November while livestock were on the range, and the stock was driven off in snow which covered the ground for three months. Therefore, the plots clipped outside of the exclosures in the first week of April, 1968, represented both domestic (summer) and game (winter) use. An attempt to assess the amount of the use due to livestock relied upon the periodic observations made on summer cattle distribution and numbers, and the use of platter counts. Defecation rates for cattle do not change appreciably during the course of the grazing season (Waite, et al., 1951) and average about 12 chips per day (Fuller, 1928; Johnstone-Wallace and Kennedy, 1944; Julander, 1955).

Competition for Forage

Estimates of differential forage utilization by bighorn sheep and mule deer were based upon census and distribution data, rumen samples, clipped plot data, and feeding site observations. These food habit studies were designed to indicate the existence and extent of forage competition.

Generally, food selection is influenced by relative availability of forage plants (Leopold, 1933: Taber and Dasmann, 1958; and others) and the relative palatability of the plants. The latter is often ex-spressed in the "preference" by ruminants for a particular food item. When different foods are available, preference for particular species can be exercised.

Colishaw and Adler (1960) have shown that preference is correlated with the content of soluble dry matter (total nutrient material) and is also indepently correlated with the soluble ash and soluble carbohydrate level in the forage. Meyer, et al. (1957), illustrated selection based upon a higher total digestible nutrient content (TDN). Often succulence and protein content are directly related as in the spring production of succulent, nutritious new growth (Moorfield and Hopkins, 1951). This can exert a selective pressure against the more palatable plants. Tisdale (1947) in palouse grasslands has noted that overgrazing of bluebunch wheatgrass (*Agropyron spicatum*) and rough fescue (*Festuca scabrella*) results in their reduction and the invasion of Columbia needlegrass (*Stipa columbiana*), Sandberg bluegrass (*Poa secunda*), Idaho fescue (*Festuca idahoensis*), and cheatgrass (*Bromus tectorum*)--less palatable grasses. Young (1943), working in a palouse grassland similar to that of Rock Creek, found the Festucas and Agropyrons giving way to such forbs as Lupinus, Potentilla, Lomatium, Achillea, and cheatgrass. Riordan (1957) states that the effect of browsing by domestic sheep and mule deer in Colorado has reduced and killed palatable browse species. The long term implications for browse viability on over-stocked deer and domestic sheep range are obvious.

Another factor influencing the palatability of forage species is the differential change in succulence and nutritive content as the plants mature (Harris, 1954).

Lignen or fiber content also influences palatability. Cranfield (1942) found that fine stemmed grasses are preferred over coarse stemmed species.

Mineral deficiencies can influence the selection of plants which can best concentrate the substance which the animal must have (Thomas, 1947). Also, deficiencies of elements in the soil, such as phosphorus, can delay the maturation of the plant as does excess nitrogen (Lovvorn and Woodhouse, 1962).

The periodic occurrence of fire not only creates new areas of forage production by increasing grassland and shrubland types at the expense of timber types, but also affects the palatability of forage plants by increasing succulence, nutrient content and herbage production of grasses and browse (Shepherd, 1963). It has been shown that grasses in the timber types are less palatable than the grasses in open grassland.

Other factors influencing forage preference, such as an increase in the utilization of a species when animals are presented with a variety of other plants (Colishaw and Adler, 1960), tend to indicate the desirability of floral diversity, both in taxa and physiognomy, on rangelands.

Rumen analyses can be used to determine the proportions of different food items in the diet of a population. Sampling over a period of time can be correlated with seasonal environmental changes. Analyses from two or more animal species sampled over the same time period from a single area can be used to indicate the degree to which these species might compete for forage due to overlapping food habits.

One quart rumen samples were collected from deer and sheep carcasses found during the field studies, hunter kills of bighorn sheep and deer, and a monthly collection of two deer per month between January and April of 1968. These were preserved in 10% formalin. The samples were analyzed at the Montana Fish and Game Department's Research Laboratory at Bozeman, and proportions of food items were determined by volumetric displacement (Norris, 1943; Martin, et al., 1946; Dirschl, 1963). The strained plant material is separated with tweezers in a porcelain pan, identified to species if possible, or at least to the major forage group of forbs, browse, and grasses, with the aid of a plant collection from the study site. Norris (1943) fed starved sheep known quantities of selected plants and concluded that although there was little value in quantitatively determining rumen contents down to species, quantitative results obtained for the broad forage categories closely correlated with the diet of the animal.

Using the food habits data, the common use and the degree of competition on the winter range involves computing the proper and the actual use levels of key forage species (Stoddart and Rasmussen, 1945). When the total annual herbage production is determined by clipping studies, the degree of overuse of key plants can be computed. The pounds of forage which each class of animal can make use of at proper use levels is calculated. The excessive use of key plant species is then computed for the existing stocking rates. This excess is the degree of competition between animals on the area. To determine the number of one species, such as deer or cattle, which must be replaced by another species, such as bighorn sheep, to achieve the desired stocking rates at proper use levels, conversion rates based upon body weight ratios are calculated. Assuming a cow-calf pair weight 700 pounds, a mule deer 125 pounds, and a bighorn sheep 125 pounds, the relative food requirement ratios are 1 cow = 5.6 deer and 5.6 sheep. It is then possible to determine the replacement of one class of animals by another.

<u>Chemical Analysis of Forage Plants</u>

Proximate analyses of plants to determine the nutrient qualities of the forage were run on grass species selected for their importance as sheep forage. Collections of these plants were made during the summer, mid-winter, and late winter. Samples were also selected on different soil types and grassland areas which roughly correspond to the summer transect sites. Sampling results could thus be related to the differential distribution of the sheep.

Einarsen (1946), Swank (1958), and others have established the correlation of forage analyses and animal condition.

The plant analyses were conducted at the Montana State University Chemistry Station Analytical Laboratory, Montana Agricultural Experiment Station, Bozeman, Montana.

Soil and Plant Relationships

During the summer of 1965, soil scientists of the Soil Conservation Service, under the direction of Ralph Dunmaier, conducted an extensive soil survey (in press) which characterized the soils of about 90% of the winter range. Due to the complex of boundaries and ownership found in the area, a good deal of the state public and federally administered land was surveyed with the private land.

Much of the soils information presented in this report was obtained from the SCS report through the courtesy of Ralph Dunmaier and Beech Warner.

Aderhold (MS) has described the major soils associations found on the study site. Briefly, the three associations which are found on the winter range, and the series underlying major or key portions are described below. The 28 soil series which represent soils found on the study area are described in detail in Table 18 on file at the Forest and Conservation Research Library, University of Montana. The eight soil series which sustain virtually all of the sheep use and most of the deer use are detailed in Table 18 and Table 19.

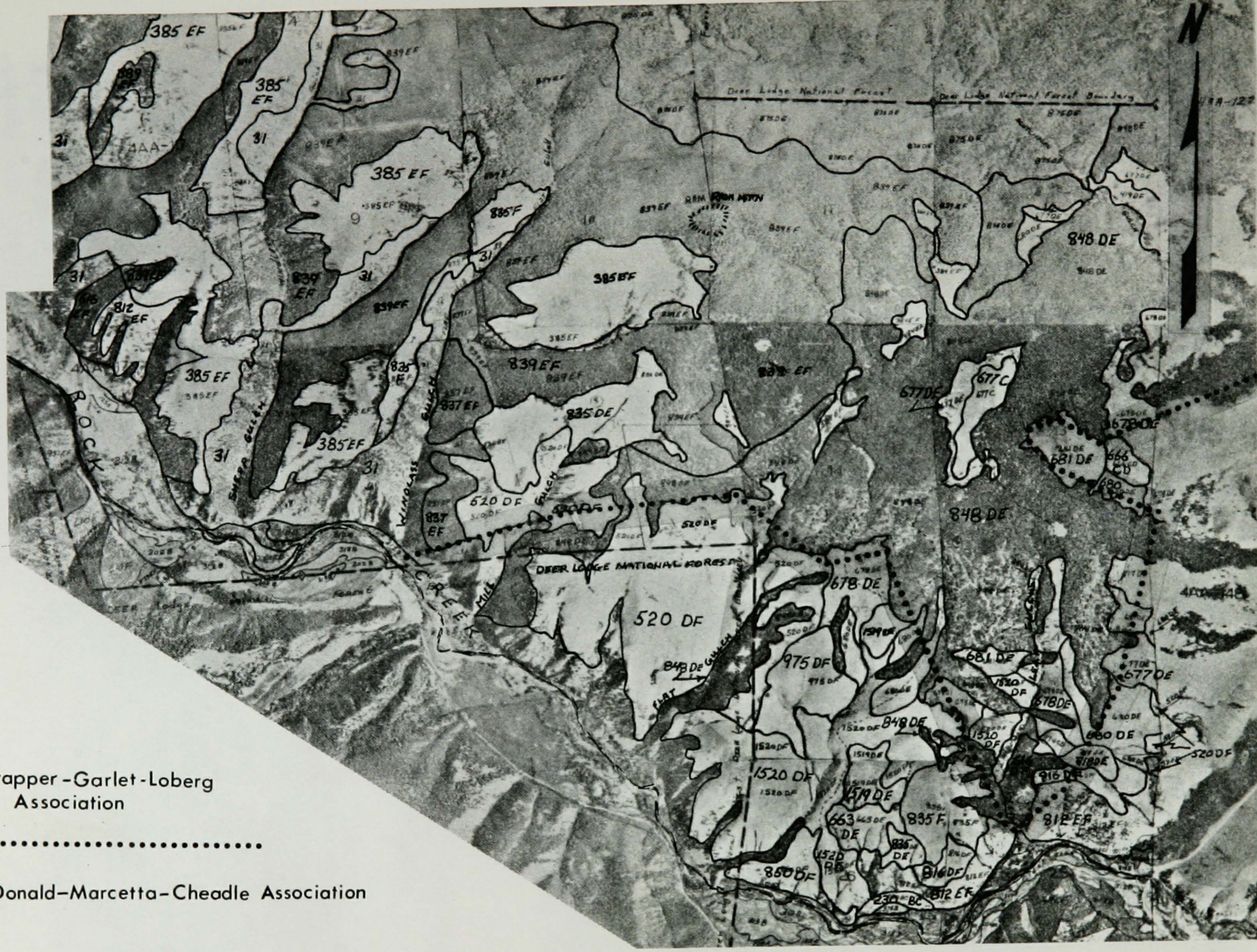
1) The Trapper-Garlet-Loberg association is found on the northwestern third of the winter range and extends southeast along the upper edge of the grassland at the timber-grassland ecotone (Fig. 20). The main soils have coarse loam subsoils (A and B horizons) underlain by calcareous limestone or argillites and quartzites. The soils are well drained and are between 12 and 40 inches deep depending on the pitch of the slope. These soils are formed under dense conifer forest, primarily

Douglas fir and lodgepole pine, between 4,500 and 7,000 feet elevation and receive about 20 inches of annual precipitation. Elk, mule deer, and black bear occupy the upper reaches of this association during the summer, migrating to the lower edge and, particularly in the case of the mule deer, into the Donald-Marcetta-Cheadle association described in Table 18.

2) The Donald-Marcetta-Cheadle association constitutes most of the remainder of the winter range which lies south and east of the Trapper-Garlet-Loberg association. These are deep, well drained soils developing in gravelly loam over quartzite and argillite bedrock. These soils support the grassland habitat type. Most of the deer and bighorn sheep winter on soils of this association. Black bear are generally found on these soils in the spring and late fall.

3) The Slocum-Bearmouth association consists of alluvial soils along high gradient streams (50+ feet per mile) with narrow flood plains. These soils are either well drained, gravelly or sandy soils, or poorly drained, moderately deep loamy soils. Upper terraces extend 20 feet above Rock Creek and support open stands of ponderosa pine with a bunchgrass-bluegrass-timothy understory. Streamside, low terrace vegetation is typical of the riparian habitat type with an abundance of willow and cottonwood. This association provides most of the winter moose and white-tailed deer habitat adjacent to the bighorn sheep winter range.

Fig. 20. Soil map of the study area.



Trapper-Garlet-Loberg Association

....

Donald-Marcetta-Cheadle Association

Table 19. Capabilities of soil series found on Rock Creek winter range*

Capability class	Indication
Dry VIe - 2	Steep, well drained, loamy soils over 20" deep; moderate permeability and holds 5" of available water; rapid surface runoff and severe water erosion hazard; used for range. -Map unit 816 DF: Maiden-Tropal complex
Dry VIe - 4	Well drained, sloping to steep; 10 to 20" thick over bedrock; moderately permeable but holds only 2" of available water; used for range. -May unit 812 EF: Tropal-Rock Outcrop association
Dry VIe - 5	Sloping to steep; well drained loamy soils more than 20" deep; moderately permeable, holding 8 to 10" of available water; medium to rapid surface runoff with a severe water-erosion hazard; used for range. -Map unit 520 DF: Maukey complex -Map units 385 and 386: Marcetta-Cheadle association -Map units 1519 DE and 1520 DF: Len loam
Dry VIIe - 1	Steep, well drained, loamy soils 10 to 20" deep; moderate permeability but holds only 3" of available water; rapid surface runoff and severe water erosion hazard; used for range. -Map unit 850: Gilispie gravelly loam
Dry VIIIs - 2	Barren and nearly barren rock outcrops and talus slopes unsuitable for cultural practices. -Map unit 31: Rock outcrop

* The SCS soil capability classification is indicated parenthetically with each of the eight series. Capability classes range from "I" (few limitations, little risk of damage) through "VII" (landforms so rough and soils so limited or shallow that they cannot produce marketable products such as crops or timber). The subclasses are indicated by small letters -- "e" meaning that the main limitation is erodability unless close plant cover is maintained, and "s" showing that the soil is limited because it is shallow, dry, or stony. The capability unit number following the hyphen indicates groups of soils similar enough to react alike to crops, management requirements, productivity, and response to manipulation. The precipitation zone in inches concludes the capability class notation (Table 18).

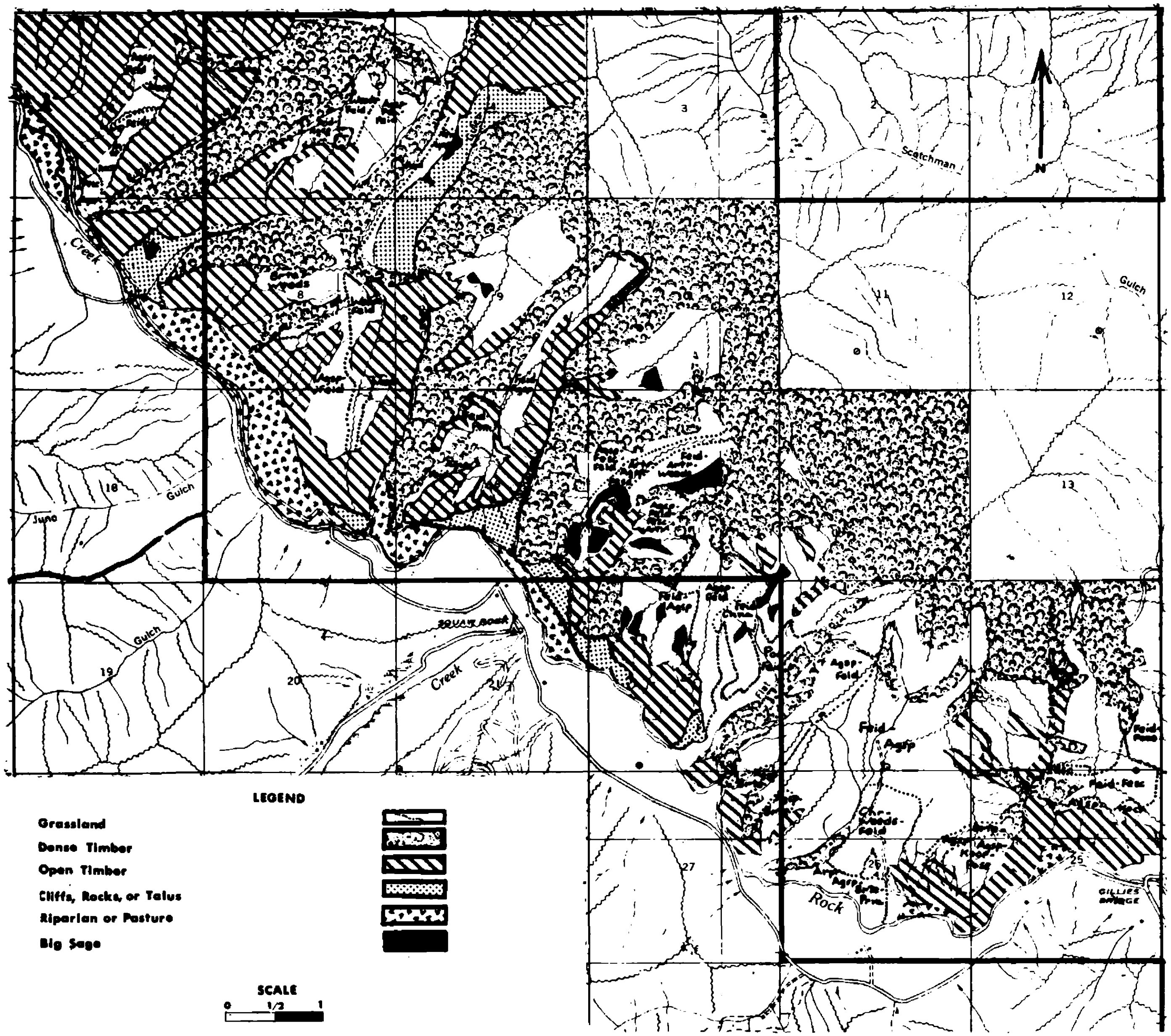
Vegetation and Floral Communities

Basic Communities

The winter range has been divided into six basic habitat types--floral communities based upon their respective physiognomic character. The habitat types are: grassland, sagebrush, open timber, dense timber, cliff and talus, and riparian-pasture (Fig. 21). These habitat types are typical of the montane palouse grassland found throughout much of the interior Pacific Northwest. Their extent and particular interspersion produce the environmental mosaic which the Rocky Mountain bighorn sheep requires. Abiotic factors such as terrain, topographic shading, and aspect are generally related to the floral communities but have not been considered in detail here.

1) The primary type of the study area is the grassland. The grassland constitutes 43% of the winter range typed in Fig. 21. The grassland habitat type occupies the predominantly south-facing slopes which often terminate in one of the other nonriparian types. The rolling terrain results in wetter-site swales, benches and terraces dominated by rough fescue (Festuca scabrella) where not overgrazed or, more commonly, Idaho fescue (F. idahoensis), Poas, mustards, big sage (Artemesia tridentata), rabbit brush (Chrysothamnus spp.), and Great Basin wild rye (Eymus cinereus). Ridge-tops are uniformly overgrazed on the study area, and are dominated by Idaho fescue, big sage, and a variety of forbs. Hillsides of 10-60% slopes constitute the bulk of the grassland type and are dominated by bluebunch wheatgrass and prairie junegrass (Koelaria cristata) when moderately grazed and Idaho fescue,

Fig. 21. Vegetation type map of the Rock Creek winter range.

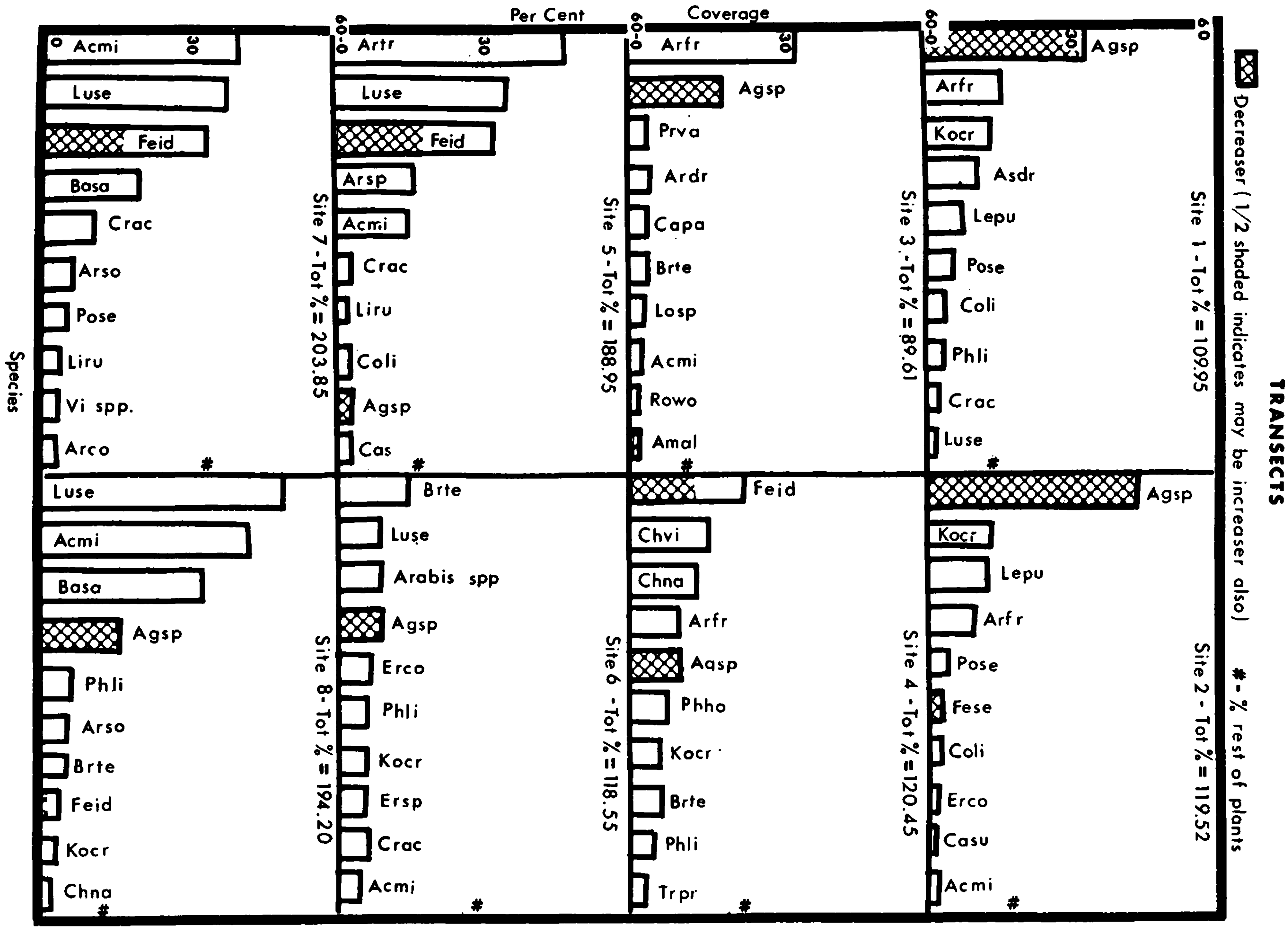


N
Scatchman
Gulch
Creek
Juno
Gulch
Creek
Rock
GILLIES BRIDGE
LEGEND
Grassland
Dense Timber
Open Timber
Cliffs, Rocks, or Talus
Riparian or Pasture
Big Sage
SCALE
0
1/2
1

forbs, and composites where heavily used. Common grassland forbs, as indicated by the transects and exclosure clippings, are: lupine (*Lupinus sericea* and *L. caudatua*), yarrow (*Achillea millefollium*), arrowleaf balsamroot (*Balsamorhiza sagittata*), cutleaf daisy (*Erigeron compositus*), milkvetch (*Astragalus* spp.), and phacelia (*Phacelia linearis*). The more mesic sites will contain ballhead sandwort (*Arenaria conjesta*) and the more xeric sites will have granite gilia (*Leptodactylon pungens*) and twinpod (*Physaria didymocarpa*). Because of the open nature of the grassland and its importance in supplying the daily food requirements of the game animals, most of the range, behavior, and distribution observations were made in this type. The majority of the 150 plant species and 35 familes listed in Table 20 are found in the grassland, which has been divided into subtypes primarily on the basis of the dominant plants as revealed by the transects and ocular reconnaissance. Details of the subtypes are illustrated in Fig. 21. The abbreviations which are used represent the first two letters of the generic and specific name and can be identified in Table 20. Thus, Agsp would be *Agropyron spicatum* or bluebunch wheatgrass.

Detailed descriptions of the density and composition of plants of this type are given in Table 21 and Fig. 22 for transects 1, 2, 4, 6, 7, and 8. Soil and range conditions indicate a rough fescue dominated climax (Morris and Dunmaier, *pers. comm.*), but rough fescue can now be found in only a few protected pockets constituting less than 1% of the total grassland area. Bluebunch wheatgrass and Idaho fescue are now the dominant bunchgrasses.

Fig. 22. A comparison of eight grassland transect sites based on per cent foliar cover.


TRANSECTS
Decreaser (1/2 shaded indicates may be increaser also)
- % rest of plants
Per Cent Coverage
Species
Site 1 - Tot % = 109.95
Agsp
Arfr
Kocr
Asdr
Lepu
Pose
Coli
Phli
Crac
Luse
Site 2 - Tot % = 119.52
Agsp
Kocr
Lepu
Arfr
Pose
Fese
Coli
Erco
Casu
Acmi
Site 3 - Tot % = 89.61
Arfr
Agsp
Prva
Ardr
Capa
Brte
Losp
Acmi
Rowo
Amal
Site 4 - Tot % = 120.45
Feid
Chvi
Chna
Arfr
Agsp
Phho
Kocr
Brte
Phli
Trpr
Site 5 - Tot % = 188.95
Artr
Luse
Feid
Arsp
Acmi
Crac
Liru
Coli
Agsp
Cas
Site 6 - Tot % = 118.55
Brte
Luse
Arabis spp
Agsp
Erco
Phli
Kocr
Ersp
Crac
Acmi
Site 7 - Tot % = 203.85
Acmi
Luse
Feid
Basa
Crac
Arso
Pose
Liru
Vi spp.
Arco
Site 8 - Tot % = 194.20
Luse
Acmi
Basa
Agsp
Phli
Arso
Brte
Feid
Kocr
Chna

2) The dense timber type comprises 29% of the winter range and extends into the back country of the John Long Mountains. The portion adjacent to the other types undoubtedly receives the bulk of the winter game use, and the above figure is therefore a bit arbitrary. The overstory is primarily Douglas fir although there are dense stands of lodgepole pine distributed throughout the type. This type is found on the north and northeast facing slopes of the study area. At higher elevations on the winter range and on northern slopes, the deep and persistent snow precludes any utilization of the pinegrass (Calamagrostis rubescens) and snowberry (Symphoricarpus alba) understory, concentrating the annuals upon the key areas. The stringers of timber are used as salting and loafing areas for cattle in the summer. Understory vegetation is sparse. These ridgetop fingers of Douglas fir and the lower elevation north slopes function as important bedding and escape cover areas for the bighorn sheep. In or near this type are found the rare patches of palatable browse plants such as chokecherry (Prunus virginiana) and serviceberry (Amelanchier alnifolia) with the single exception of these plants in a grassland type which is detailed in Table 21, transect 3. This type has been invading grassland areas, particularly on the northwest slopes.

3) The open timber type occupies dry, south facing, often steep and rocky hillsides. Frequently Douglas fir will dominate the common juniper at about a 60:40 ratio. This type constitutes 18% of the winter range. The canopy is open, and bluebunch wheatgrass forms a low density understory. This type serves as an important bedding area for game. Also, in severe weather it supports most of the grazing. However, the herbaceous plants in this type are rarely overgrazed. The open timber

type is primarily found in rocky areas immediately adjacent to the valley of Rock Creek.

4) The cliff and talus type is intimately associated with both of the timber types and rises, often vertically, from Rock Creek or its feeder draws. This type constitutes 4.0% of the winter range. The extensive talus slopes of Windlass, Sheep, and the unnamed gulch to the south of Capron Creek rise 500 to 1,000 vertical feet at a 75% pitch. Limestone outcrops, known as "hoodoos," protrude like 100-foot fingers from the cliffs and slides adjacent to Rock Creek. These cliffs and the overhangs and caves associated with them are used by the sheep for escape cover and, in times prior to this study, as lambing grounds (Neal, Rotts, and Wyman, pers. comm.). Evidence of intensive past use is indicated by the web of ~~trains~~ trails found in the cliffs and on the talus. The spare vegetation consists primarily of an occasional Douglas fir and a bluebunch wheatgrass understory. The talus fans found at the base of the cliffs support the best stands of chokecherry to be found on the range although the plant density is low and the area covered by this association of rock and chokecherry amounts to less than three acres for the entire winter range. The plants are browsed by deer in heavy winters, and about 30% are severely hedged. Sheep use these areas for about one week each April but clip the new growth of the bluebunch wheatgrass and cheatgrass, which seem to be among the first plants to green-up on the winter range. While clipping the short new growth, the sheep virtually ignore the chokecherry shrubs all around them. Seepage of water is indicated by mosses and ice overhands. The entire formation is rotten and unstable.

5) The riparian-meadow type between the northeast side of Rock Creek and the bulk of the winter range embraces 3.5% of the study area.

The riparian produces most of the browse found on the winter range. This consists primarily of willow (*Salix* spp.), black cottonwood (*Populus trichocarpa*), thin-leafed alder (*Alnus incana*), and mountain maple (*Acer glabrum*) with a sedge-wire rush (*Juncus balticus*) understory in the moist sites and ponderosa pine (*Pinus ponderosa*) with a shrubby potentilla (*Potentilla fruticosa*) understory and a poa-timothy (*Phleum pratense*)-carex ground cover.

The riparian has been extensively cleared and seeded to pasture grasses and legumes such as timothy and clover (*Trifolium* spp.). These pastures winter the cattle and sheep of local ranchers and provide a hay crop each summer for use the following winter. This bottomland vegetation provides browse for moose, elk, and both white-tailed and mule deer in the winter. During the course of this study, virtually no sheep use was noted in the bottoms although use has been reported during critical periods of considerable snow accumulation in previous years (Wright, *pers. comm.*). The meadows are generally covered by one-half to two feet of snow through the winter even though the slopes above are bare. The haystacks attract elk from the southwest side of Rock Creek, and in spite of such precautions as elk panels, depredation occurs. During the winter it is not uncommon to find mule deer in the riparian, the pastures, and crossing the creek.

6) The sagebrush type constitutes 2% of the winter range and is dominated by big sage with a forb-Idaho fescue understory. This type is found on some flats of the ridges and bottoms and on portions of the

hillsides, frequently in a bowl-shaped defilade of any aspect except north. A detailed description of this type is found in Table 21 for transect 5. The sagebrush types are generally surrounded by grassland and reflect past overgrazing (Fig. 21 and Table 21; Part III: History and Land Use).

Range Condition and Trend

Range condition is a term describing the vegetation found on a site at a given point in time in relation to the climax vegetation. The stage of seral recession or progression is intimately related to the intensity of disturbance and the nature of the soil. From observations of relict areas on the site and the analyses of soil scientists such as Ralph Dunmaier (pers. comm.), a reconstruction of the climax vegetation for the key portions of the winter range was attempted.

Plants are categorized as decreasers, increasers, or invaders (Table 22).

Decreasers are climax species which are highly preferred as forage. They decrease in relative abundance under excessive use. A range is considered to be in excellent condition if 70 to 100% of the plant cover is in the decreaser class (SCS report, in press).

Increasers are species present in climax communities which increase in greater relative abundance with the decrease or elimination of the more palatable or fragile climax plants. The increase can be quantitative or relative Increasers are often grazed with relish as range degenration progresses and are, in turn, the victims of negative selection. Invader plants are often "weedy" forbs and annuals which constitute less than 2½% of the climax community.

The SCS report (in press) states that range is in good condition if 51-75% of the climax vegetation is present, in fair condition if 26-50% of the climax vegetation is present, and in poor condition when less than 25% of the climax vegetation is contained on the site.

The bulk of the Rock Creek winter range consists of shallow, dark (when wet) well drained gravelly loams of the 10-19 inch precipitation zone. The climax vegetation on these soils is dominated by such decreasers as rough fescue, bluebunch wheatgrass, Richardson needlegrass, Columbia needlegrass, and sticky geranium. Forbs and increasers may constitute as much as 10% of the climax community. Increasers are Idaho fescue, danthonias, prairie junegrass, Sandberg bluegrass, needle and thread, pussytoes, Eriogonum, sagewort (fringed sage), lupine, balsamroot, and other forbs. Invaders such as cheatgrass brome, rabbitbrush, and annual mustards characterize a range in poor condition on these soils. Total dry weight yield of climax vegetation on these soils should approach 1,250 pounds per acre. Palatable forage plants should amount to about 850 pounds per acre although only about half of these weights can be expected in dry years. Ellison (1960) states that the best measure of the abundance or volume of vegetation is given by weight production. Measure of cover is next in validity for calculating vegetation abundance.

Fig. 22 gives the plant composition and density for the major species found on each transect site. They are coded to illustrate the ecological status of decreaser plants. Table 21 summarizes the transect data for each species which accounts for more than 1% of the total transect cover. Table 23 presents the presence and weights of all plants clipped. These data are summarized in Table 24 and quantify the successional stage of each site when compared with the climax species discussed above.

The transects indicate that no site found in the grassland type can be considered as being in a climax state. Transect number 2 most nearly approaches the climax vegetation with about 42% decreasers (including rough fescue) present in the sample.

The exclosure sites were determined solely on the basis of bighorn sheep sightings. These were the focal points of sheep activity in the winter of 1966-67. Hence, we might expect that the sheep utilized the grassland areas in the most advanced stage of plant succession.

Methods of correlating cover measurements with weight have been developed (Hickey, 1961). Foliar composition as determined by plot frames with inclined pins which intercept the vegetation has been closely correlated with actual clipped weights. Wilson (1960) in California found that for all grasses in plots clipped for a two-year period the foliar cover averaged 54% and weight averaged 55%. The cover percentages and weight percentages for decreasers in transects and exclosures, respectively, are summarized in Table 24 and Fig. 23.

If, then, we are able to roughly relate the data from the transects to that of the exclosures, it becomes obvious that the exclosure sites are in a much higher seral stage than the transect sites. Transect number 2, which is significantly higher in the per cent cover decreasers than the other transects, was the only transect placed in

Fig. 23. Per cent decreaser plants at each transect and exclosure site.

Per Cent Decreaser Plants

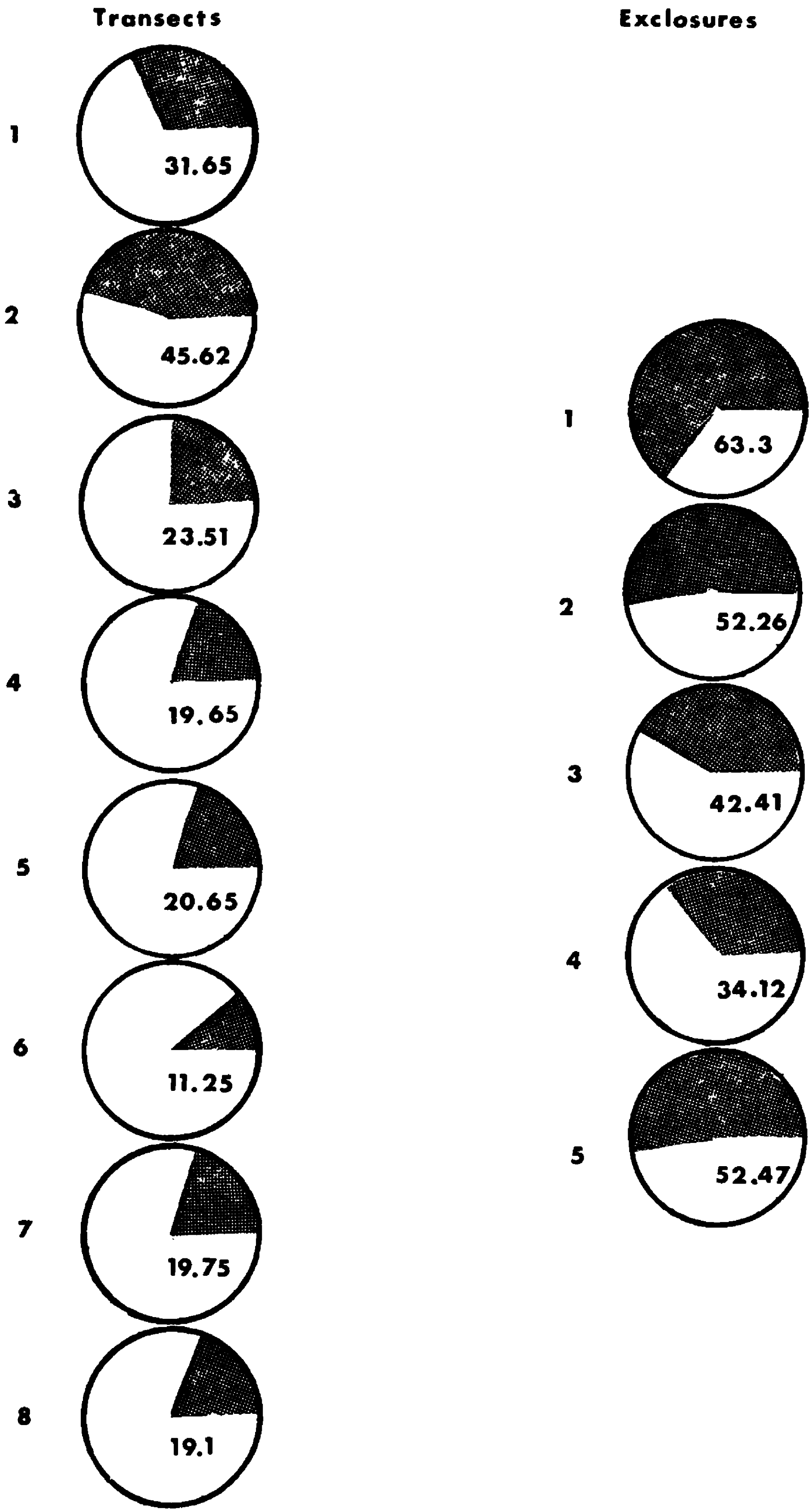


Table 24. Per cent decreasers in transects and exclosures and description of seral state

	Transect (% by cover)	Exclosure (% by weight)
1	31.65 - fair	63.70 - good
2	45.62 - fair	52.26 - good
3	22.51 - poor	42.41 - fair
4	19.65 - poor	34.12 - fair
5	20.65 - poor	52.47 - good
6	11.25 - poor	
7	16.70 - poor	
8	19.60 - poor	

nearly the same location and habitat type as an exclosure (exclosure number 2).

Perusal of all three types of data-species composition, density, and dry weights, indicates a range in fair condition at best. Only exclosure number 5 showed a significant amount of rough fescue.

The almost complete lack of palatable browse species on the winter range is a striking feature of the transect and type-map data. Transect site number 3 contained the most extensive patch of palatable browse plants found on the winter range (5.6% chokecherry and 2.8% serviceberry.

Intensive browsing results in a reduced proportion of palatable shrubs (Cottam and Evans, 1945). Garrison's (1953) clipping studies on winter ranges in Oregon and Washington suggest the processes involved in browse elimination on overstocked game ranges. Removal of portions of the annual twig growth generally stimulated twig production and increased the availability of the growing portions of the plant by altering growth forms. However, flower and fruit production was decreased. Russo

(1964:24-25) describes the partial or total elimination of shrubs due to overuse by the Kaibab deer herd. Ceanothus, once characteristic of the ponderosa pine overstory, had all but disappeared. Thus, repeated over-browsing results in the elimination of preferred browse species.

It is plausible to ascribe the virtual absence of preferred shrubs on the Rock Creek winter range to the concentration of game and livestock in such numbers (Part IV: Vegetation and Forage Competition) that the resultant competition for the palatable species has led to their drastic reduction or elimination. The reduction of palatable shrubby vegetation and an increase in less palatable browse species tends to substantiate this hypothesis. Big sage (Artemesia tridentata) is sparingly used by game species on the study area. One instance of bighorn sheep use has been observed. Several big sage plants had been stripped of leaves on several leaders during the period of extensive snow accumulation in January and February of 1968. Most plants have not been touched. Aging of big sage plants in a sagebrush type between Windlass and Mill Gulches revealed that the older plants were 45 plus or minus five years old. This corresponds with the period of intensive homesteading and severe overuse of the range (Part VI: History and Land Use). As no dead or dying stems or crowns of preferred browse species can be found, we can probably date the elimination of the preferred browse plants from this period. There are only a few relict areas with small, residual populations of preferred browse plants.

The trend of the range describes the change in the condition of the range. If succession is progressing toward the climax or terminal plant community for a particular site, then the trend is "up." If seral regression is taking place, the trend is "down." Because of varying land use practices, natural catastrophies and climatic changes, oscillations of range condition are the rule, under natural conditions. The dynamic nature of the term implies a change over a given period of time, usually since the last change in "direction." The most reliable methods of determining the direction and rate of the trend involve periodic determinations of the range condition. The fragility of a site and its response to treatment can be predicted when a knowledge of its past use and the direction and rate of range trend can be employed.

From a comparison of present data with a 1936 U. S. F. S. (Table 26) range inventory map, I conclude that:

1) the overall range trend is down, although at a very slow rate;

2) the range encompassed by the Boomer-Brewer operation has deteriorated at an accelerated rate;

3) there has been a considerable invasion of the grassland by less preferred shrubs, such as sage and rabbitbrush.

Due to the infrequent range analyses conducted in the area under consideration here, the speed of the invasion of these shrubs cannot be ascertained. However, rabbitbrush is now being overutilized to the extent that many plants are dying.

4) There is a slow invasion of tree species.

5) A few sites such as those found on section 5 have improved since 1936.

Another range survey was conducted in 1954 by Buechner (1960:120, 131). The two sites sampled showed "an exceptionally deteriorated wheatgrass-bluegrass community." These transects were run in the same area as transect number 6 of this study--the state "school" section 16.

Production

The potential of the winter range to support the herbivores living there was determined by quantifying the productivity of the grassland communities.

Plots clipped within the exclosures during the summer of 1967 have yielded the dry weight production data presented in Table 23 for each species which is summarized below in Table 25.

Table 25. Herbage production in winter range exclosures summarized for all species and for four common grasses* (dry weight in grams/species/exclosure, pounds in parentheses)

Exclosure	Production	
	Grasses	Total
1	184.24 (368.48)	414.02 (828.04)
2	327.51 (655.02)	476.96 (953.92)
3	354.41 (708.82)	617.93 (1235.86)
4	321.89 (643.78)	921.18 (1842.36)
5	103.11 (206.22)	216.63 (433.26)
mean	258.23 (516.46)	529.34 (1058.68)

*Idaho fescue, bluebunch wheatgrass, Sandberg bluegrass, and prairie junegrass.

The only site which approaches the 1,250 pounds per acre production criteria given for the soils of this area by the SCS (in press) is exclosure number 4. Exclosure number 5 produces about one-third of this figure. The poundage of grass produced reveals that in the case of exclosure number 4, the high production is due to the production of forbs and that, in fact, this is the poorest of the exclosure sites in terms of successional status and the production of grass.

Table 26. Comparative range data - 1967 and 1936

Site		Dominant Plant Species		
Section	Subtype	1967	1936	Change in Grassland Type
4		Feid	Feid	
5		Feid, Agsp	Agsp, Brte, Feid	Open timber invasion
8	*1	Luse, Acmi, Basa, Agsp	Agsp, Feid, Acmi	
	*2	Agsp, Luse, Acmi	Agsp, Feid, Acmi	
	3	Weeds, Feid	Feid, Agsp, Brte	
	1		Agsp, Weeds, Feid,	
	2		Artr, Agsp, Brte	
10			Agsp, Feid, Weeds	Sage invasion
22	*	Agsp, Luse, Feid	Agsp, Feid, Brte	
27	*	Feid, Chvi, Chna, Artr	Feid, Agsp	

*1967 transect or exclosure data

The four grass species were chosen on the basis of consistent representation, in both the plots and the exclosures. These grasses will be used to compare a preferred forage class between clippings made in summer and spring in the utilization studies discussed later. Although other grasses are found (Table 23), they represent only 16.3% of the weight of all grasses clipped, 75% being cheatgrass from exclosure 4.

Utilization

To determine the reason for discrepancies between the expected constitution of the plant communities on the winter range and that which was actually found, the grazing pressure exerted upon the range plant communities was quantified by forage utilization studies.

The exclosure sites were clipped again the following spring. Plots were clipped both inside and outside the exclosures. An analysis of variance was conducted on clippings made inside the exclosures at time one and time two. The statistical tests showed no significant difference at the 95% confidence level in summer and spring herbage weights for the four grasses tested, when the test was based upon weight totals for all five exclosures (Table 27). Due to the similarity in weight of the selected grasses which were protected from grazing and clipped in the summer and after the winter, one can assume that any difference in the weights of those plants outside of the exclosures would be due to animal use and not such factors as regrowth or degeneration of plant tissue. If regrowth and degeneration occurred to any significant degree, they evidently balanced each other, masking any total effect.

The statistical treatment also showed that each exclosure site was significantly different from any other.

Table 27. Summer and spring weights of four grasses clipped inside of winter range exclosures (dry weight in gm/exclosure)*

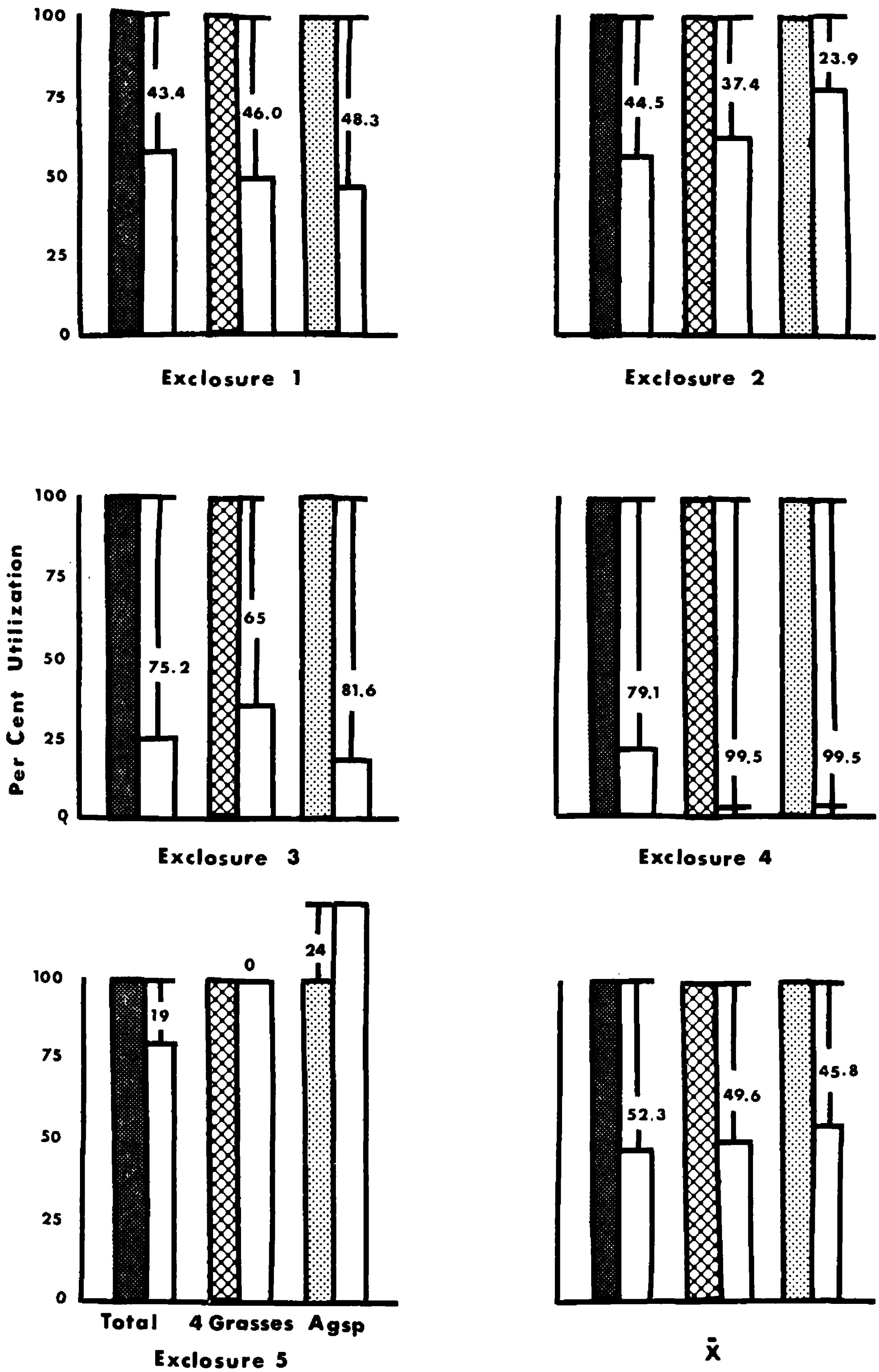
Exclosure	June-July 1967	April 1968
1	184.24	201.10
2	327.51	256.20
3	354.41	411.60
4	321.89	278.90
5	103.11	48.50
Total	1291.16	1196.30

*Idaho fescue, bluebunch wheatgrass, Sandberg bluegrass, and prairie junegrass.

Examination of Fig. 24 and Table 28 reveals the significant differences in herbage weights between the summer and spring clippings for all exclosures except number 5. Although exclosure 5 showed a 19.06% decrease in total herbaceous material, the four grasses examined exhibited no use, and weights for bluebunch wheatgrass increased 24.09%. Observations during the same winters indicate no sheep used this site.

Exclosure site 4 exhibits a spectacular utilization of forage. The four palatable grasses which were measured together exhibited a 99.47% decrease in weight. Bluebunch wheatgrass was examined separately for all exclosures to check the utilization figures and to attempt to identify any forage preference for that species. This species exhibited 99.46% utilization at exclosure number 4. Bluebunch wheatgrass was so abundant that its value dominates the grass averages.

Fig. 24. Per cent utilization of all species, four common grasses, and bluebunch wheatgrass on all exclosure sites.


Per Cent Utilization
100
75
50
25
0
43.4
46.0
48.3
Exclosure 1
44.5
37.4
23.9
Exclosure 2
75.2
65
81.6
Exclosure 3
79.1
99.5
99.5
Exclosure 4
19
0
24
Total
4 Grasses
Agsp
Exclosure 5
52.3
49.6
45.8
$\bar{X}$

The total herbage declined 79.14%, reflecting in part the preponderance of annual forbs in the plant species composition. The succulent forbs and the annual, cheatgrass, decreased to about two-thirds of its summer weight, primarily due to the annual loss of plant tissue, leaving bluebunch wheatgrass as the major plant, by weight, on the site.

This site was the area which also appeared in the most degraded stage of seral regression. On this site about 50 head of domestic sheep were turned out annually between approximately 1950 and 1955. Cattle were also on this range and continued to graze this site until 1963. After two years of little domestic use, about 600 domestic sheep and 40 head of cattle were turned out by the Boomer-Brewer ranching operation onto 1,400 acres which included exclosure site 4. At this time, between 85 and 125 domestic sheep died (reports vary) within a two-week period. The loss was ascribed by Mr. Brewer to coyote predation and by Mr. Wilford Dufour of the SCS to lupine poisoning. Since 1965 approximately 15 horses have been wintered on this piece of range annually. This brief recapitulation of the land use history of the site indicates a probable cause of the deteriorated condition of the range which is kept in poor condition by continued intense horse, cow, and game grazing. The effect of this overgrazing is indicated by analysis of the data obtained from exclosure 4 and transects 7 and 8. The evidence is that overgrazing results in an increase in annual grass plants, such as cheatgrass, and forbs, such as lupine, which are less preferred by the grazing animals than the perennial bunchgrasses.

The high production of bluebunch wheatgrass at exclosure 4 reflects its durability and a stimulation of growth under heavy use although continued overuse will soon lead to its replacement by the less preferred plants due to reduced seeding as has been the case for rough fescue and other preferred plants.

Exclosure sites 1 and 2 display use at about the 40% level for the grasses (Fig. 24). This is under, although approaching, the maximum recommended utilization of 50% for most bunchgrasses in good-to-excellent condition in this region (Forest Service Range Analysis Field Guide, 1963:640). To rehabilitate bunchgrass ranges in fair condition, grass utilization of between 25 and 40% is recommended. For ranges in poor condition, 10 to 25% use is recommended. For the Rock Creek winter range, utilization of grasses should probably not exceed one-third of their total weight, with local exceptions depending upon the condition of the site.

Over-utilization of the four grasses sampled is seen at exclosure site 3. Bluebunch wheatgrass is particularly overgrazed. This is significant at exclosure 3 because there was a much greater opportunity to exercise a choice. The table below illustrates the proportions in which each of the four grasses appear at exclosure sites 1-4.

Table 29. Proportions by weight in which four grasses appear at exclosure sites 1-4

Exclosure	Grass						
	Bluebunch wheatgrass		Idaho fescue		Prairie junegrass		Sandberg bluegrass
1	100	:	0	:	8.3	:	0.13
2	100	:	1.6	:	33.0	:	1.00
3	100	:	40.0	:	18.0	:	5.00
4	100	:	0.5	:	0	:	2.30

The utilization of Idaho fescue at exclosure number 3 is at the 76.37% level. For prairie junegrass utilization was 93.96%; however, this figure is questionable due to the relatively small initial (summer) weight. I feel confident in relegating bluebunch wheatgrass to the role of the major forage producer and the most preferred plant in the grassland type.

Other studies, carried out on ranges where it is abundant, indicate that rough fescue is the first plant to disappear under overgrazing by cattle, horses, and elk, but not domestic sheep (Morris, pers. comm.; Blood, 1965). Whether rough fescue would assume the first rank in the forage preference if it were more abundant is a moot point. There is not enough rough fescue present at Rock Creek to give a reliable answer. An indication of its value may be inferred from its utilization at exclosure 5. Although, at this site, the utilization of the four grasses was zero and bluebunch wheatgrass actually increased in weight, the rough fescue, which was the second most important grass by weight, was utilized at the 47.2% level. The patterns of distribution of the game animals occupying the winter range during the winter of 1967-68 (Part III: Behavior) indicate this use is attributable to the occasional mule deer and not bighorn sheep.

As we were unable to clip the exclosures in the fall, the question arises as to the amount of grass utilization by domestic livestock. Cow chips were counted at the two exclosures most likely to be used by cattle. At exclosure 2 there was no evidence of use by cattle. At exclosure 3 several 1/20 acre transects revealed use at about 3 chips each 1/20 of an acre or 60 chips per acre. At the rate of 12 defacations per day, this indicates five days' use per acre, or a forage consumption of about 90 pounds per acre during the grazing season, about 7.3% of total plant production in the few acres on which cattle graze on the winter range.

Livestock use at exclosure 2 and 3 is light. The bulk of the grazing at these two sites is due to wildlife.

None of the exclosure sites could be considered primary cattle range as defined in the Forest Service Range Analysis Field Guide (1963: 251). Slopes exceed 40-50% and in the case of exclosures 2 and 3, are a considerable distance from water, making the site less attractive to cattle which cannot be expected to travel more than one-half mile to water in steep country (Stoddard and Smith, 1955:392). Horses, because of their greater rustling ability, are not affected by the pitch of the hill at exclosure 4, and the results are evident in the deteriorated condition of the bighorn sheep winter range frequented by the 16 horses wintered here by Mr. Brewer.

Although game is common in this area, concentrations were not what they were at exclosure site 3, yet the condition at this site was the poorest, trend was downward, and the utilization the heaviest of all the sites sampled.

To summarize, the range is in poor-to-fair condition generally due to the overuse by deer and locally by horses. The bighorn sheep are concentrated in grassland sites which are in the best condition of all the sites which I sampled.

Rumen Analyses and Feeding Sites

To calculate the nutritional plane and the competition for forage for the game animals wintering at Rock Creek, it was necessary to determine the proportions in which the forage classes appear in the diets of each of the major classes of ungulates. This was done by employing analyses of rumen samples and feeding site observations.

Feeding site observations to determine the food habits of bighorn sheep have been extensively used in two recent Montana studies. On a winter range comparable to that of Rock Creek, Constan (1967) reported utilization of grass for 72% of his observations of feeding bighorn sheep in the Gallatin Canyon, Montana. Bluebunch wheatgrass and Idaho fescue sustained the highest use of all plant species, the former being preferred. These two plants constituted 60% of the winter diet. The use of bluebunch wheatgrass declined between January and March as it became less available due to constant use. The diets of mule deer and elk in the Gallatin Canyon contained 7% and 30% grasses. As with the bighorn sheep, bluebunch wheatgrass and Idaho fescue were the most preferred grasses, with bluebunch wheatgrass being used in excess of its relative abundance. Constan (1967) classified fringed sage as a forb which, with lupine, constituted the greater portion of the 17% forb consumption. Browse was taken in 8% of the observations, big sage and rubber rabbitbrush being the primary species. A rumen sample from a ram killed illegally during February showed 95% grass, 3% forbs, and 1% browse by per cent volume.

Schallenberger (1966) on the Sun River, Montana, winter range, found grasses, forbs, and browse were used 36, 21, and 43% respectively by the bighorn sheep. Rumen samples obtained during the hunting season showed 86.5, 8.9, and 1.9% by volume of grasses, forbs, and shrubs, respectively. It appears that rumen analyses yield higher percentages of grass and grass-like plants than do the feeding-site observations made during the same months.

Bighorn sheep rumen samples were collected by Dr. P. L. Wright of the Department of Zoology, University of Montana (pers. comm.) between May 1958 and April 1959 on the National Bison Range. Personnel of the Montana Cooperative Wildlife Research Unit (Craighead, pers. comm.) made several collections on Wildhorse Island in 1959 and 1960. The unpublished data from these two collections and the results of the rumen analyses from the present study constitute the sum of bighorn food habits information for Montana west of the continental divide (Table 30 and Fig. 25).

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Table 31 is based upon sheep rumen analyses and is illustrative of the importance of grasses in the diets of bighorn, Nelson's, and Dall sheep and also shows the relative importance of the other food classes.

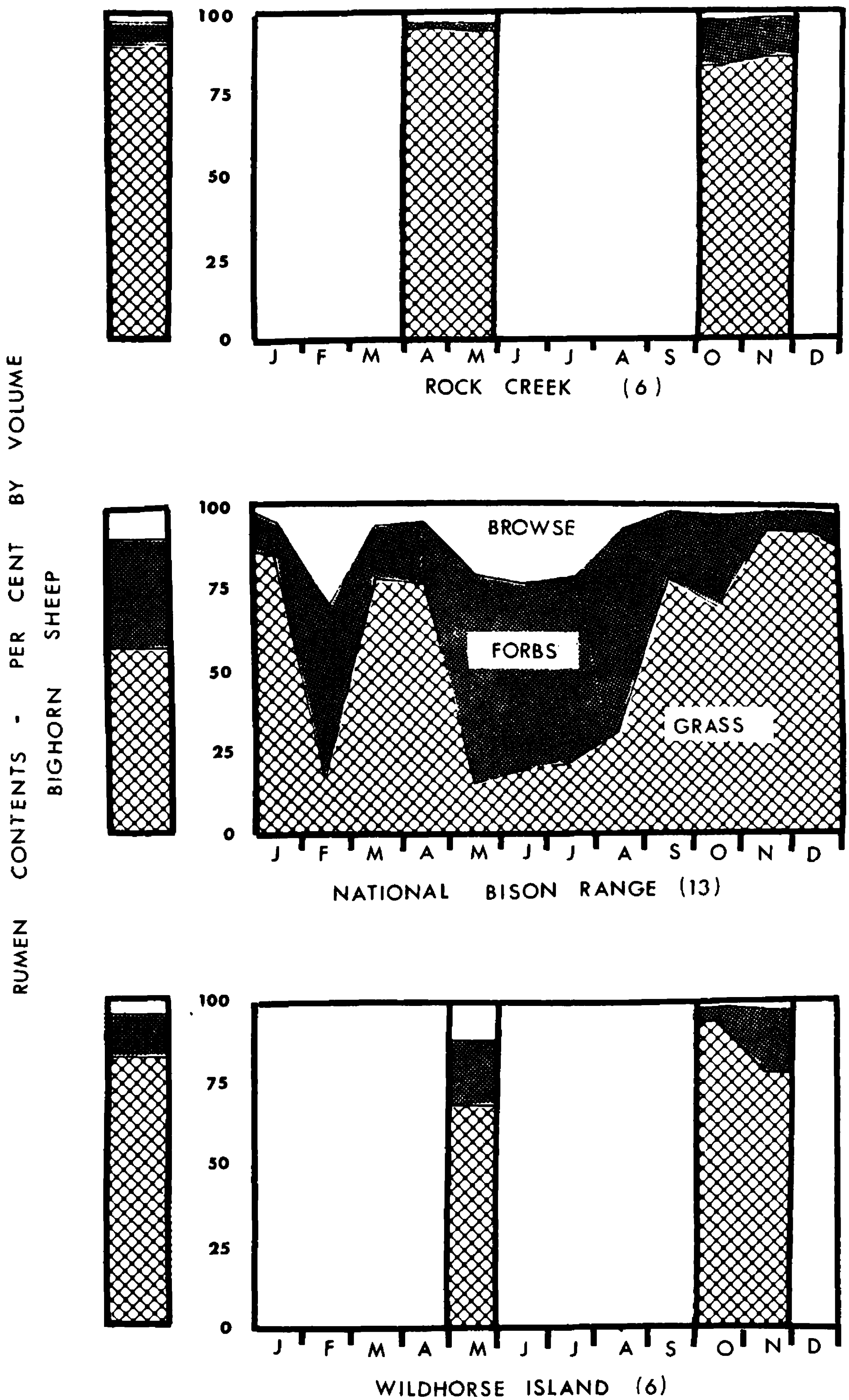
The rumen analyses show that the Rock Creek bighorn sheep, with an average grass consumption of 90.09%, is more of a grazing animal than any of the other reported populations. The time of year the sample was collected seemed to have little influence on the relative composition of food items in the diet of the Rock Creek bighorns although a tendency to consume more forbs was indicated in the fall. Although identification

Table 31. Summary of some published literature on yearly bighorn, Nelson's and Dall sheep food habits*

Source	Per cent by volume				Race
	Grasses or Grasslike Plants	Forbs	Browse	Misc.	
Colorado					
Jones and White (1951)	89.5	4.6	4.5	1.2 (dirt)	canadensis
Moser (1962)	74.65	6.2	19.13		canadensis
Wyoming					
Honess and Frost (1942)	50.8	29.6	19.4		canadensis
Montana					
Couey (1950)	63.0	17.0	14.0	6.0	canadensis
Alaska					
Murie (1944)	81.4		10.2	8.4	dalli
Nevada					
Barrett (1964)	72.5	9.5	18.0		nelsoni
British Columbia					
Sugden (1961)	29.3	9.1	61.6		californiana

*Not all during a single year or season year.

Fig. 25. Food habits of the bighorn sheep of Rock Creek, Wildhorse Island, and the National Bison Range.


RUMEN CONTENTS - PER CENT BY VOLUME
BIGHORN SHEEP
100
75
50
25
0
J F M A M J J A S O N D
ROCK CREEK (6)
BROWSE
FORBS
GRASS
100
75
50
25
0
J F M A M J J A S O N D
NATIONAL BISON RANGE (13)
100
75
50
25
0
J F M A M J J A S O N D
WILDHORSE ISLAND (6)

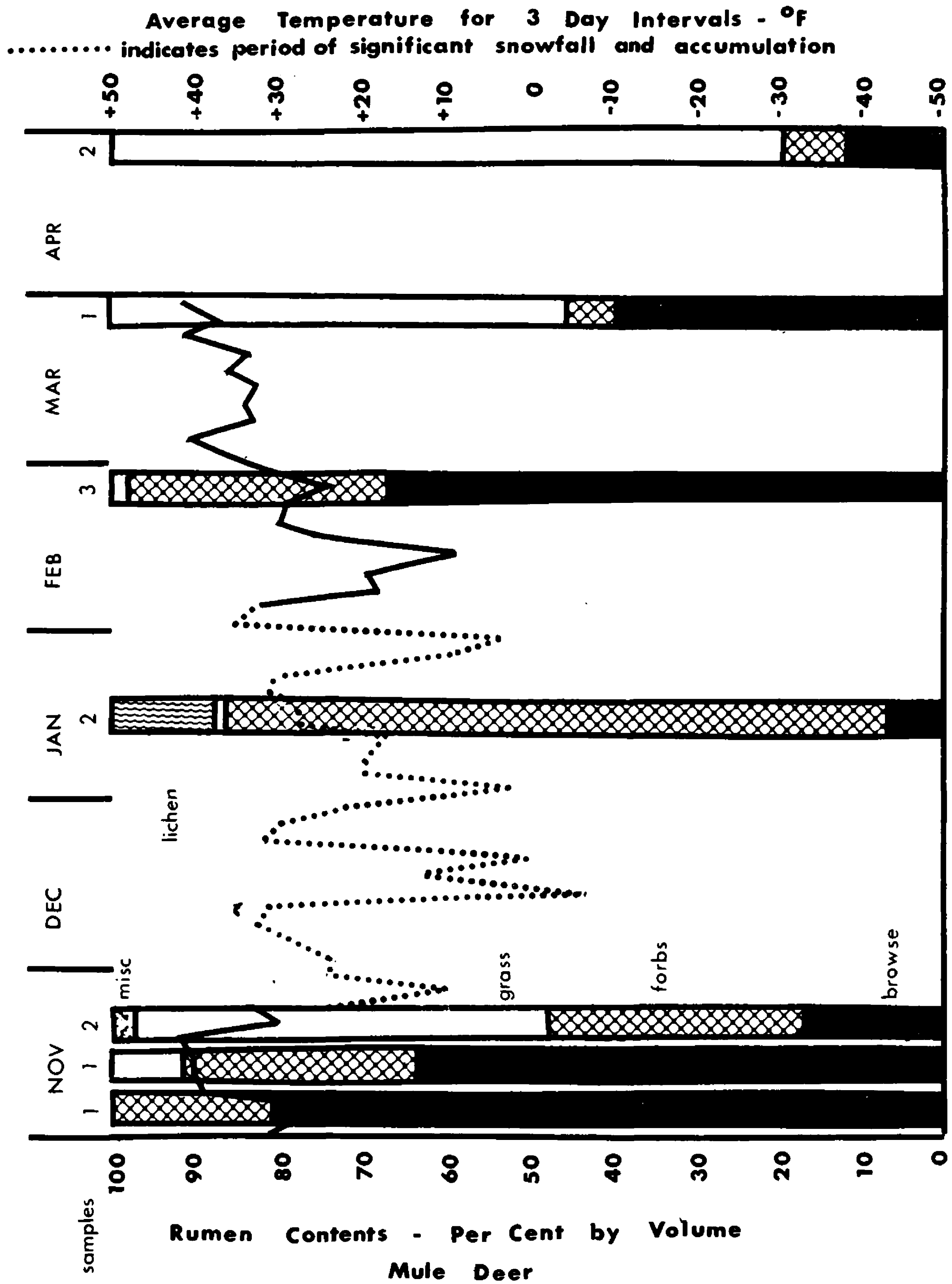
of the grass species found in the rumens was difficult, bluebunch wheatgrass and Sandberg bluegrass were occasionally identified (Table 30).

Forbs constituted 7.41% of the diet of the Rock Creek sheep although the average for samples taken during the fall approached 18%. The most important forbs seemed to be cutleaf daisy, lupine, strawberry (*Frageria* spp.) and kinnikinnick (*Arctostaphylos uva-ursi*).

Browse accounted for 2.96% of the diet and appeared to be primarily Douglas fir and snowberry.

The 12 mule deer rumens secured during the fall and winter of 1967-68 provide an interesting contrast to those of the bighorn sheep (Table 32). Averages for November through April show 27.54, 38.02, and 31.69% consumption of grasses, forbs, and browse, respectively. The significance of the difference between the sheep and deer stomach contents is masked somewhat by the difference in climate between the winters of 1966-67 when five of the six sheep rumens were secured, and 1967-68 when all 12 deer rumens were secured. The winter of 1966-67 was warm and wet, although extended. During December 1966 only on ten days did the temperature fail to reach 32° F. The winter of 1967-68 began early and was quite severe, although short. December of 1967 saw 19 days when the temperature failed to reach freezing. Feeding habits of the deer appeared to reflect the cold temperatures and accumulation of snow (Fig. 26) in that the proportion of browse and lichen which are found in the timber types show an increase in the rumen samples. Although the number of rumens analyzed was quite small, I tentatively feel that the bighorn sheep did not appear to be as flexible in their dietary habits as the mule deer. The rumen samples of the Rock Creek bighorn

Fig. 26. Monthly mule deer food habits, snow cover, and temperature, Rock Creek.


Average Temperature for 3 Day Intervals - °F
.... indicates period of significant snowfall and accumulation
+50
+40
+30
+20
+10
0
-10
-20
-30
-40
-50
NOV
DEC
JAN
FEB
MAR
APR
misc
lichen
grass
forbs
browse
100
90
80
70
60
50
40
30
20
10
0
samples
Rumen Contents - Per Cent by Volume
Mule Deer

sheep do not show the large variation in forage types in response to the different climatic conditions of the seasons in which samples were secured. Table 33 details the rumen analyses of a sheep and two deer shot within one week of each other in the same habitat type on Rock Creek in late November, 1967.

Table 33. Rumen contents of mule deer and bighorn sheep killed on Rock Creek during November, 1967

	Per cent by volume			
	Grasses	Forbs	Browse	Misc.
Deer (2)	49.4	17.0	30.4	2.7
Sheep (1)	97.7	0.6	1.8	

Hundreds of feeding site observations of mule deer indicate the over emphasis that the rumen analyses tend to put on the use of browse plants. Over 95% of mule deer feeding observations occurred in the grassland habitat type during periods of normal winter weather. The effect of the unusually severe early storms was to drive the animals into the trees bordering the grassland type where the canopy intercepted the snow. This was reflected in the pronounced decrease in deer sighted in the grassland during the period of heavy snow accumulation. Foraging and bedding activity in this type was increased. The primary browse taken was conifer (primarily Douglas fir) needles and small twigs (Table 32). Artemesia spp. was the second most important browse item.

Studies on the National Bison Range in a similar habitat as that of Rock Creek, indicate again the flexibility of mule deer food habits. In this case an improvement in range conditions over a six-year period these species are consumed in about the same proportions as they are present, by weight, in the plant community. The 80:20 browse to grass ratio approaches the weights of annual growth of shrubs to grass in Knoche's study area (*pers. comm.*).

Indices of Competition

An assessment of the amount of competition between cohabitants of a winter range is a desired and usually final step of any comprehensive study of range condition and food habits. Competition can occur when there is common use of an inadequate supply of forage. The competitive use of a plant is approximately the per cent use above proper use.

As previous discussions have indicated, grasses when available are at present the preferred forage on Rock Creek of both mule deer and bighorn sheep.

We shall use the production and utilization data for the four common grass species (Fig. 24) to evaluate the degree of competition between sheep and deer. The following conditions are assumed, based upon the data which has been presented:

1) the four grasses (bluebunch wheatgrass, Idaho fescue, prairie junegrass, and Sandberg bluegrass) constitute a minimum of 90% of the diet of the bighorn sheep.

2) The four grasses constitute a minimum of 40% of the diet of the mule deer.

3) Proper use for these grasses on a range site in generally "fair" condition is no more than one third of the annual production of the grasses.

4) Sheep and deer each consume about 3.2 pounds of dry forage per day. This figure is comparable to the four pounds of range forage required by a 125 pound mule deer as determined by feeding trials (Hill, 1956:401).

5) The sheep range encompasses 25% of the deer range. There are 800 deer on the winter range. However, since the range common to both deer and sheep is the best of the deer range, over 50% or at least 400 deer occupy the sheep range.

6) Competition from domestic stock is negligible. To realize this assumption for the entire winter range, the nonuse at site 5 would have to balance the overuse at site 4. To confirm this, competition was computed for the entire winter range, and also for the portion south of Mill Gulch where competiton from livestock has been shown to be minimal based upon utilization figures for sites 1, 2, and 3.

7) Acreages computed for winter ranges of the deer and sheep (Fig. 27) are essentially correct.

8) The sheep population desired will represent the number before the present die-off--or about 200 bighorn sheep.

Computation of competition

Case 1 - entire winter range (herbage figures in pounds):

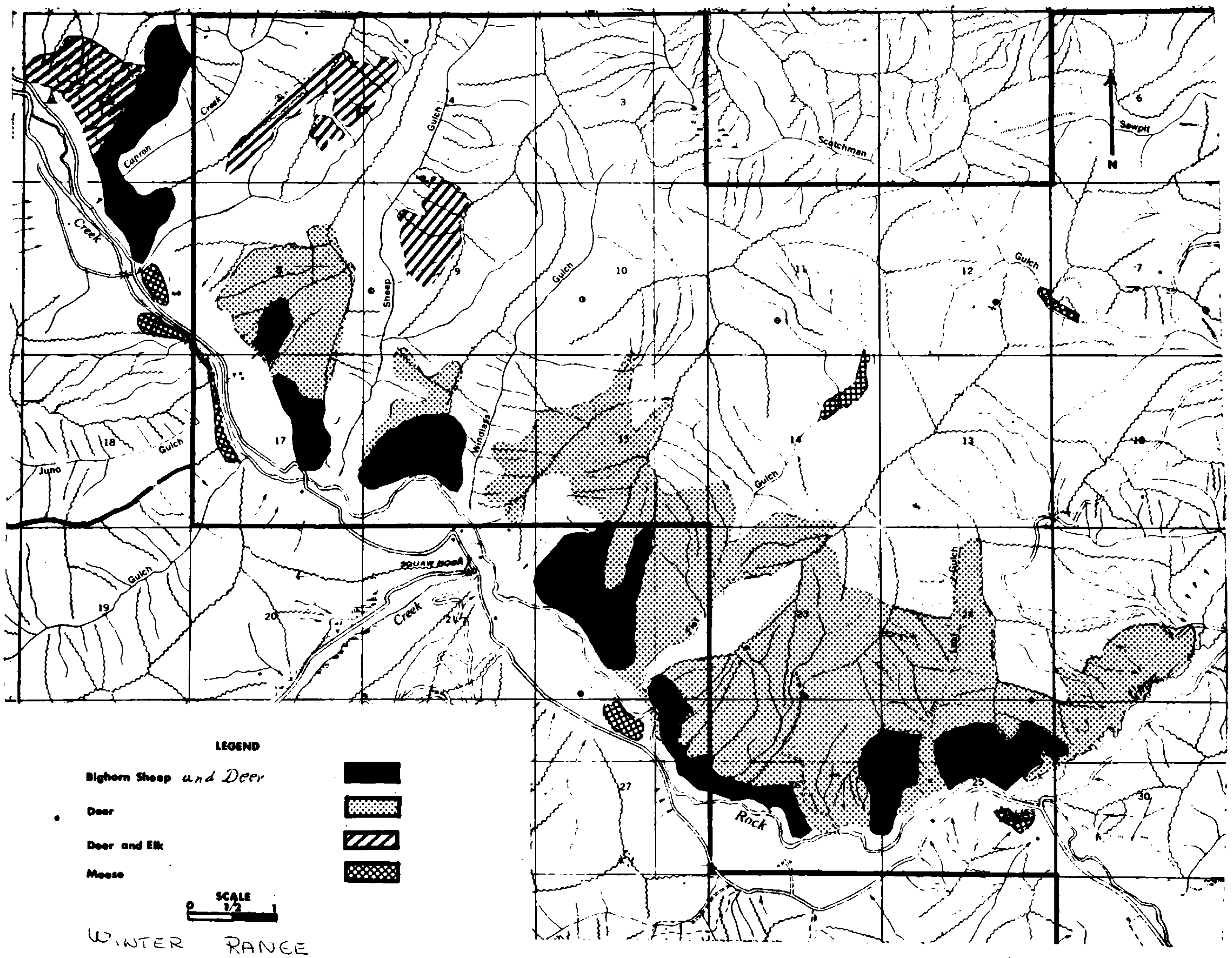
Available forage yield	Proper use	Actual use	Sheep days/yr
562,583	168,771	353,883	40,150

1) Forage available at proper use
- sheep days/yr x forage consumption/day

forage left for deer

2) $$\frac{\text{forage left for deer}}{\dfrac{\text{forage consumption of deer}}{\text{number of days deer use range/yr}}} = \text{number of deer which can be supported with 200 bighorn sheep on the winter range}$$

Fig. 27. The distribution of wild ungulates on the Rock Creek winter range.



WINTER RANGE

3) number of deer present
- number of deer which can be supported with 200 bighorn sheep
$$\frac{\text{number of deer present} - \text{number of deer which can be supported with 200 bighorn sheep}}{\text{number to be removed + 25\% of present number (annual increment)}}$$
= total number of deer to be removed

1) $\begin{array}{r} 168{,}771 \\ -\ 115{,}632 \\ \hline 53{,}139 \end{array}$

2) $\dfrac{\dfrac{53{,}139}{1.28}}{180} = 231$

3) $\begin{array}{r} 400 \\ -231 \\ \hline 169 \end{array}$ + 25% of 400
= 269 deer to be removed at proper use of the entire winter range with 200 bighorn sheep

Case 2 - portion of winter range encompassed by sites 1, 2, and 3:

Available forage yield	Proper use	Actual use	Sheep days/yr
304,310	91,292	174,247	22,500

1) $\begin{array}{r} 91{,}292 \\ -\ 64{,}800 \\ \hline 26{,}429 \end{array}$

2) $\dfrac{\dfrac{26{,}492}{1.28}}{180} = 115$

3) $\begin{array}{r} 250 \\ -115 \\ \hline 135 \end{array}$ + 25% of 250

= 197.5 deer to be removed

At the present stocking of deer and sheep, about 210 deer would have to be removed to eliminate competition between the species and allow range recovery.

These figures indicate that to regenerate the range and support 200 bighorn sheep, about 270 mule deer must be removed. The calculations represent a crude index to the magnitude of the competition problem. Although the 25% increment will change as the deer are removed, depending on how long (in breeding seasons) the reduction takes and the proportion of mature does in the harvest, the figure for the desired number of sheep and deer will remain constant and represent a goal. The increment figure is not a large proportion of the 169 and 135 deer desired for Case 1 and Case 2 respectively and can be annually updated.

Cattle do consume enough forage to support roughly 45 bighorn sheep or mule deer through the winter. Since cattle ranching is an important and traditional form of land use on Rock Creek, some degree of competition with game animals is to be expected due to livestock ranching. However, the impact of cattle use can be reduced without a reduction in the number of livestock by such range management procedures as the fencing of pastures to better control cattle, particularly with regard to relatively small areas of key winter game range which constitute a fraction of the summer ranges used by the cattle.

PART V: NUTRITION, CONDITION, AND GROWTH

Literature and Methods

The physical condition in free ranging wild ruminants is an important index of the quality of their environment, particularly the range resource (Severinghaus, 1955; Taber, 1957). In most cases, the quantitative determination of physical condition involves autopsies of the animal in question. Thus, restrictions in acquiring specimens which can be used for condition analyses are imposing in the study of a rare species or a declining population. There are no published data which indicate parameters of physical condition for bighorn sheep in either natural or controlled situations. Indices of condition in deer have been developed by the use of body weight-skeletal size and body weight-reproductive tract weight correlations (Taber and Dasmann, 1958). Hammerstrom and Camburn (1950) used body weight-hog dressed weight correlations. Bandy, et al. (1956), developed a condition index based upon body weight-heart girth and hindfoot length ratios.

Fat deposition, particularly in bone marrow (~~Cheatum~~ Cheatum, 1949; Bischoff, 1954; and O'Gara and Greer, 1968:87), and around the kidneys (Riney, 1955) has been measured to give an index of physical condition in cervids and antelope.

~~Salye~~ Selye (1950) implicates adrenal hypertrophy and hyperplasia (with a corresponding increase in adrenal weights) in "The General Adaptation Syndrome" of the body to environmental stress. Christian and Davis (1955) investigated adrenal responses to stress and suggest that animal populations will maintain healthy relationships to their environment and not display cyclic fluctuations when they are held at about 50% of the environmental carrying capacity. Hughes and Mall (1958) correlate adrenal weights to the physical condition of blacktailed deer.

Cowan and Wood (1955) relate growth in blacktailed deer to their nutritional regime. Verme (1963) found a decrease in fetal development of deer with low protein diets, particularly during the last one-third of gestation. Fawn mortality was directly related to the size of the fawns at birth. Domestic sheep which are on a poor nutritional plane also produce small lambs with resultant high lamb mortality (Thompson and Thompson, 1948, 1953). Thompson and Thompson (1948, 1953) working with domestic sheep, show a direct relationship between milk yield and nutritional plane of the sheep during late pregnancy and lactation. Kitts, et al. (1956), believe that much of the post natal mortality in fawns may be ascribed to lactation inadequacies. Kitts, et al. (1956), and Ullrey, et al. (1967), note the desirability of rapid growth in fawns. This enhances survival during the post weaning period of winter stress. Ullrey, et al. (1967), show that gains in whitetailed deer fawns are directly related to the protein intake after birth. In summary, the analyses of physical condition and stress should reflect the adequacy of the nutritional plane of the bighorn sheep and deer wintering on the study area. The nutritional plane determines the reproductive success and the survival of the sheep and deer, particularly of the newborn.

The nutritional requirements of bighorn sheep have never been defined and can only be inferred from standards given by the National Research Council's report of the committee on animal nutrition for domestic sheep (1964 ~~1954~~). We have also used the nutrient requirements established for mule and white-tailed deer in our treatment of bighorn sheep nutrition.

The relationship between the chemical composition of forage, its digestibility, and the physical condition and size of animals which utilize the forage has been investigated by French, et al. (1956), Swank (1958:34) and Cook and Harris (1968), among others. The influence of range condition upon the nutritive value of forage plants has been noted by Cook and Harris (1950). Feeding trials (Cook, et al. 1953), indicate that sheep prefer the more palatable and nutritive meristematic portions of forage plants. As these portions are removed, the nutritive content declines proportionately. The crude protein of shrubs declined by 40% after the first instance of use by browsing animals. Grasses which contained 4% crude protein before grazing contained only 3% protein after 50% utilization of the grass. As the sheep continued to feed in the same area, the nutritive capacity of that portion of the range degenerated. In general, the longer ruminants remain upon a particular piece of range, the more they use and reuse the same plants and with each instance of use the nutritive content of a plant decreases.

Literature and Methods

To determine the nutritional regime of bighorns wintering at Rock Creek, rumen samples were first analyzed to establish the dietary habits of the animals. Then, proximate analyses were run on grass species which were selected for their importance as bighorn sheep forage to determine their nutrient qualities. Collections of these plants for analysis were made during the summer, mid-winter, and late winter.

To establish the physical condition of the Rock Creek bighorn sheep, I have compared the kidney fat index (as described by Riney, 1955) and the weights of the Rock Creek bighorns with those of sheep collected at the National Bison Range. The range conditions on the Bison Range and the parameters of physical condition (Table 35) in these sheep, suggested that the Bison Range bighorns were in as good a condition as could be found for bighorn sheep under relatively natural conditions. Therefore, I used these animals as controls. The 12 Bison Range bighorn sheep were collected monthly in 1958 and 1959 by personnel of the Department of Zoology at the University of Montana. The portions of the Rock Creek sheep considered in this section were obtained through the cooperation of successful permittees who killed sheep in 1966 and 1967, and from autopsies of sheep found dead during the course of the field studies.

During each of the months of January, February, March, and April of 1968, two mule deer were collected from the grassland type on the study site, and autopsied. The bulk of this data, in addition to that secured from four deer autopsied during the fall, 1967, hunting season, will be considered in a later report. However, certain aspects pertinent to the discussion of bighorn ecology, such as the rumen analyses are considered in this paper.

The size of an animal reflects such factors as age, heredity, and, as noted above, nutrition. To assess the influence of nutrition on the bighorn sheep, selected skeletal measurements were compared in the Rock Creek sheep before and after the 1965 decline. The predecline bighorn population of Rock Creek, as has been noted, showed many characteristics of nutritional well-being such as twinning, low levels of parasitism, and an increasing population, indicative of high survival rates through the winter. It was hoped that morphological comparisons within the same population and between similar age groups would minimize any variation due to nonenvironmental causes.

Similar measurements, for comparison, were made for sheep of the National Bison Range and Wildhorse Island.

I have used horn growth, body weights and skull measurements to indicate nutritional and genetic differences in the bighorn sheep considered in this study. Tooth replacement and wear was used to age each animal after the criteria established by Taylor (1962). As the lower jaw was indispensible for aging, and because it is commonly found in the field, portions of the jaw were selected for measurement. Also, since skull bones measurements were employed in establishing the taxonomic relationships of North American wild sheep, identical measurements were found in the literature and used in my comparisons. A description of the measurements is found in Table 36 and Fig. 28.

The three measurements from Cowan (1940) were found by Bradley and Baker (1967:114) to be the most distinctive when distinguishing _Ovis canadensis canadensis_ from the only other subspecies for which there is a considerable amount of skeletal material--i.e., _Ovis canadensis nelsoni_. Therefore, the three skull measurements are used here to distinguish genetic differences between the Rock Creek bighorn sheep and several other bighorn populations from western Montana.

Table 36. Descriptions of skeletal measurements of bighorn sheep*

Number**	Description
1	Postdental length: least distance between alveolus of third upper molar and anterior margin of paroccipital process on same side.
2	Zygomatic width: greatest distance between external margins of zygomatic arches taken on jugo-squamosal suture.
3	Basilar length: greatest distance between inferior lip of foramen magnum and lip of premaxillae on mid-line.
4	Jaw length: greatest distance between posterior lip of mental foramen to posterior rim of the angle of the ramus.

*Measurements 1-3 from Cowan (1940).
**Numbers correspond to those of Fig. 28.

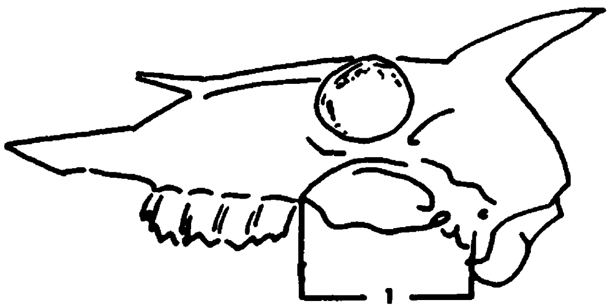
Horn length, basal horn circumference, and maximum horn spread were also used to distinguish possible effects of nutritional differences between the pre- and postdecline Rock Creek bighorn sheep.

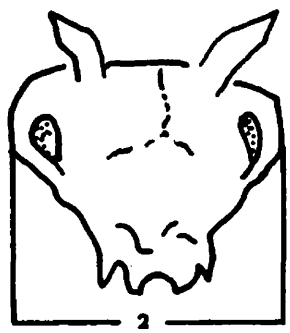
Mayr, _et al_. (1953), described the quantitative criteria used by Cowan (1940) in his revision of the bighorn sheep. The 75% rule of taxonomists employed by Cowan (1940) was also used in the present study. That is, if 75% of population A is different from 97% of population B for a character (or 90% of A is not overlapped by 90% of B), the taxonomists assign the two populations subspecific rank. Cowan (1940) used 2.56 standard deviations to represent this degree of difference. Mayr, _et al_. (1953:146), suggest use of the "coefficient of difference" (C. D.) which is the difference in the means of a character of the two populations divided by the sum of their standard deviations.

$$\text{C. D.} = \frac{M_B - M_A}{\text{S. D.}_A + \text{S. D.}_B}$$

Fig. 28. Illustration of skeletal measurements used in this study.
1) Post dental length
2) Zygomatic width
3) Basilar length
4) Jaw length

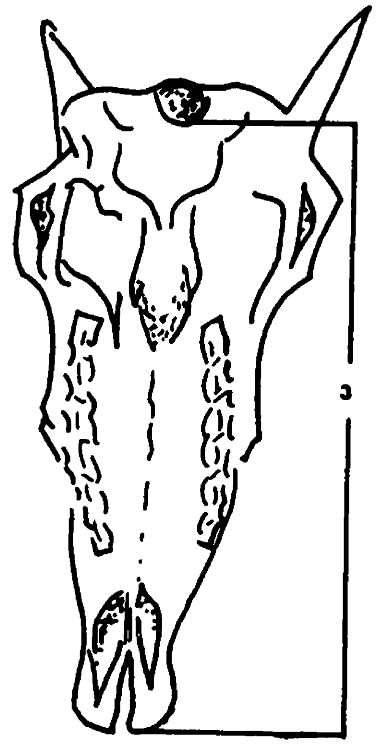
Skull profile

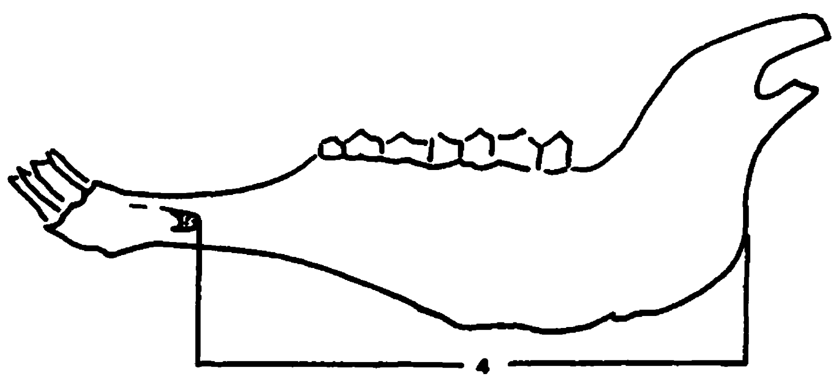




Skull (posterior)

Skull (ventral)





Jaw

In this way, the differences in standard deviations in the population samples are accounted for, whereas they were not when Cowan's calculations were made. If a C. D. of 1.28 or more is obtained, Mayr (1953:146) advises subspecific separation of the populations.

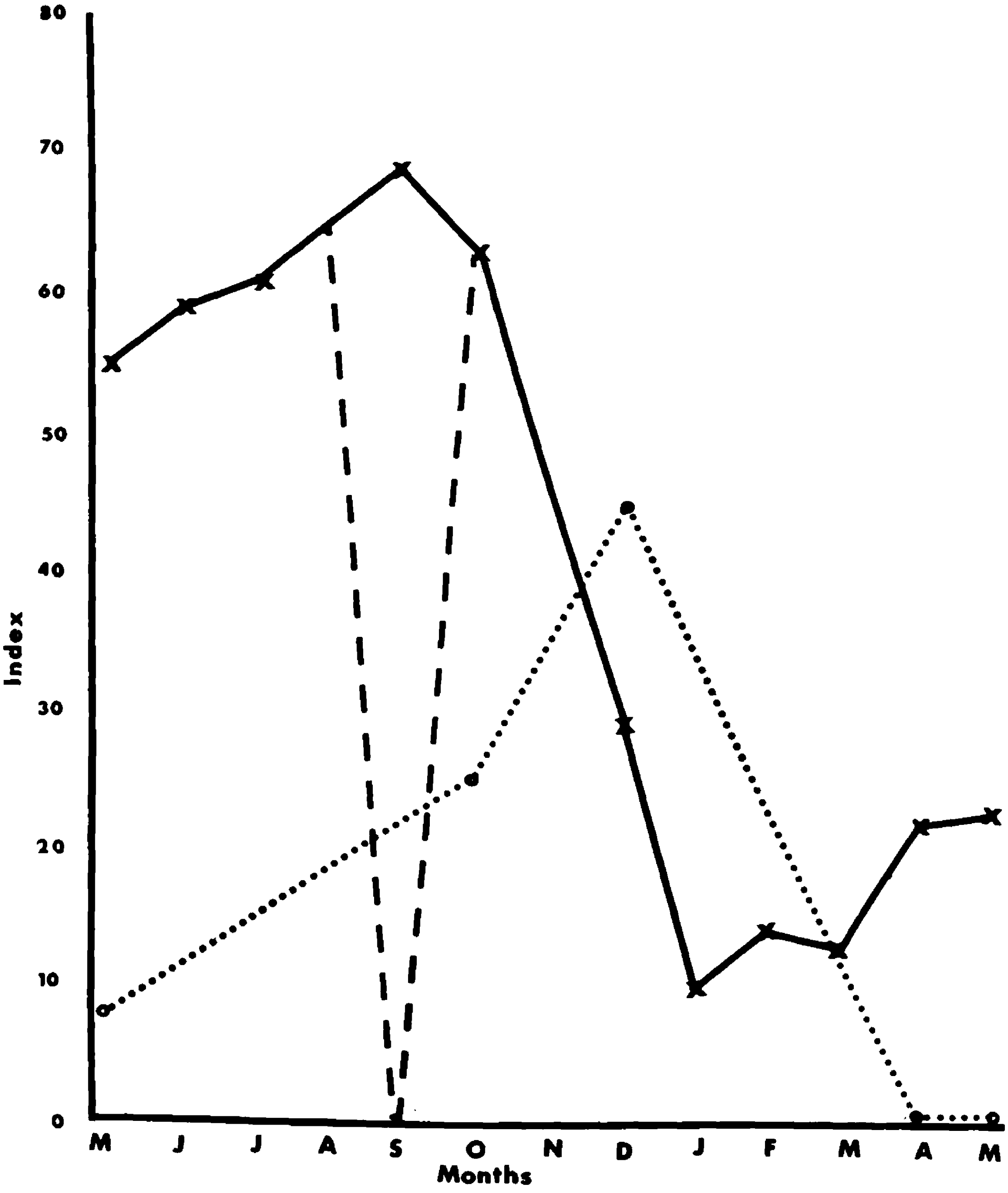
Condition

All of the data secured in the autopsies of the bighorn sheep are presented in Tables 35 and 37.

Fig. 29 compares the kidney fat indices of 13 healthy National Bison Range bighorn rams collected in 1958-59, one Bison Range ram collected 9 September 1967, in obviously poor condition and sacrificed for study, and the four Rock Creek bighorns from which we were able to obtain kidneys. The first three Rock Creek sheep depicted on the graph (reading left to right) were shot; the others were natural deaths (Table 37).

Although the data are limited, we can see the following general patterns: 1) condition in the male bighorn sheep of the Bison Range improves in the early spring, reaches a peak during the late summer, declines markedly during the breeding season and improves slowly throughout the winter; 2) the Rock Creek sheep are in a generally poorer condition, throughout the year, than those of the Bison Range. The major difference of the Rock Creek sheep from the Bison Range sheep, other than the generally poorer condition, is the lack of improvement during the winter. The other general patterns of the annual cycle of condition seem to be similar. 3) The reliability of the kidney fat index as a measure of condition is emphasized by the poor condition of the Bison

Fig. 29. Kidney fat indices of Rock Creek, the National Bison Range, and Wildhorse Island bighorn sheep. (The September Bison Range ram was in poor condition and sacrificed as a study specimen.)



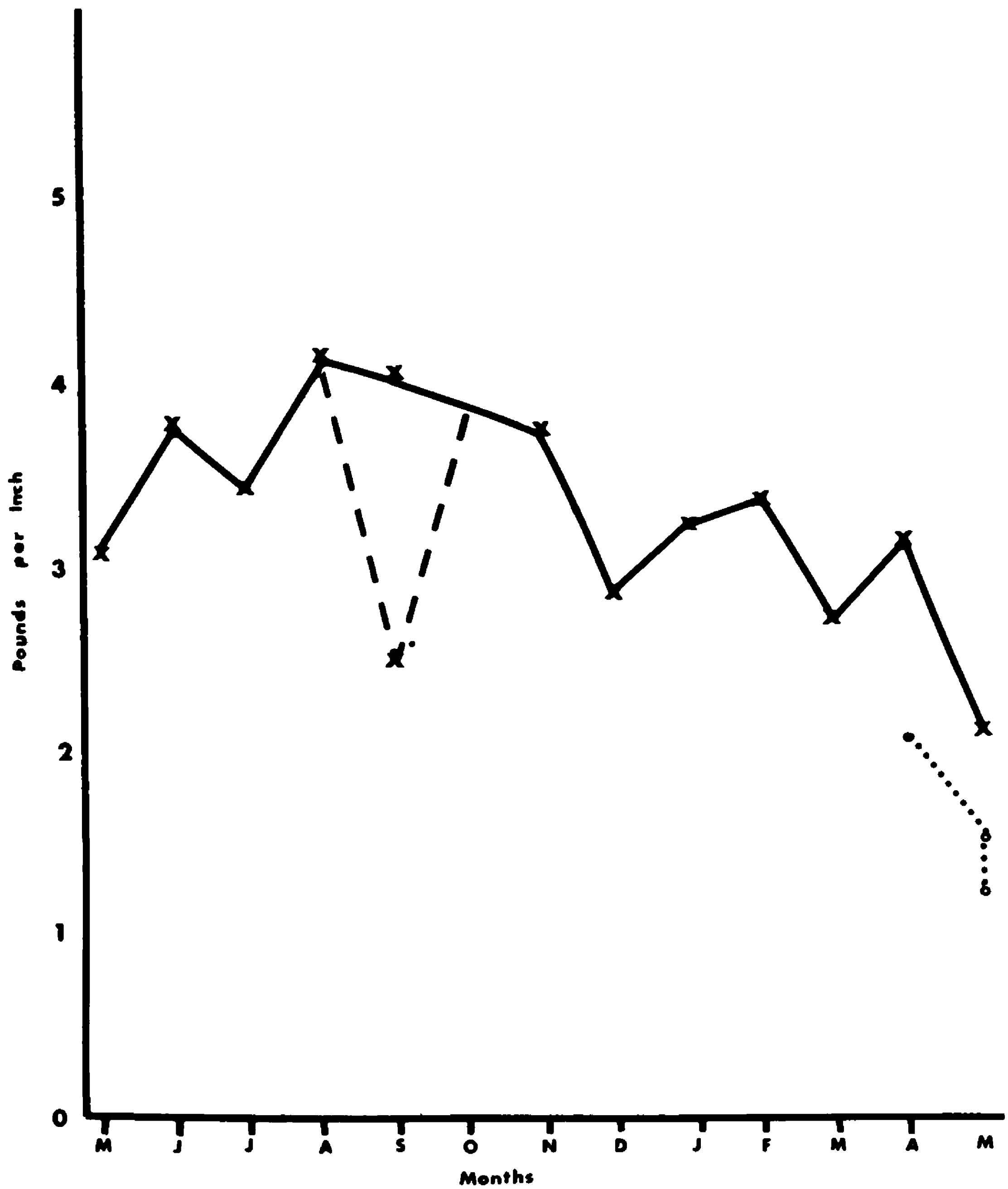
Kidney Fat Index

x—— Bison Range 1958-59
x— —Bison Range 1967 (ill)
o····· Rock Creek

Range ram shot during what should have been the period of peak physical condition. The animal was sacrificed for a study specimen because observations over a period of several days indicated that he would probably die of natural causes. His weight-size ratio (Fig. 30) was far below the other rams of the Bison Range, and a severe internal infection and numerous gall stones were found during the autopsy. 5) The Rock Creek sheep are in such extremely poor condition in early spring that the kidney-fat index is zero. It is at this time that the demands of pregnancy are the greatest.

Fig. 31 illustrates the difference in adrenal weights found in the Bison Range and Rock Creek bighorn sheep. The following conclusions, based upon the data presented in Fig. 31 may be drawn: 1) The adrenals of the Rock Creek sheep are nearly twice as heavy as those from the Bison Range sheep. This presumably indicates an increased production in corticoids, which has been shown in other species to be associated with an increased susceptibility to disease. (Part II: Population Dynamics.) 2) There does not appear to be a short term or seasonal response in adrenal weights of the Bison Range sheep. Chronic stress results in an increase in adrenal weight. Individual variations seem to be of the same magnitude throughout the year (Fig. 31). 3) The Bison Range ram which was in such poor physical condition showed the smallest adrenals. The Bison Range has experienced a period of range regeneration and the small adrenals of the single 1967 Bison Range ram might reflect this general long-term improvement of the habitat. More samples are needed.

Fig. 30. Body weight per unit length of Rock Creek and Bison Range bighorn sheep.



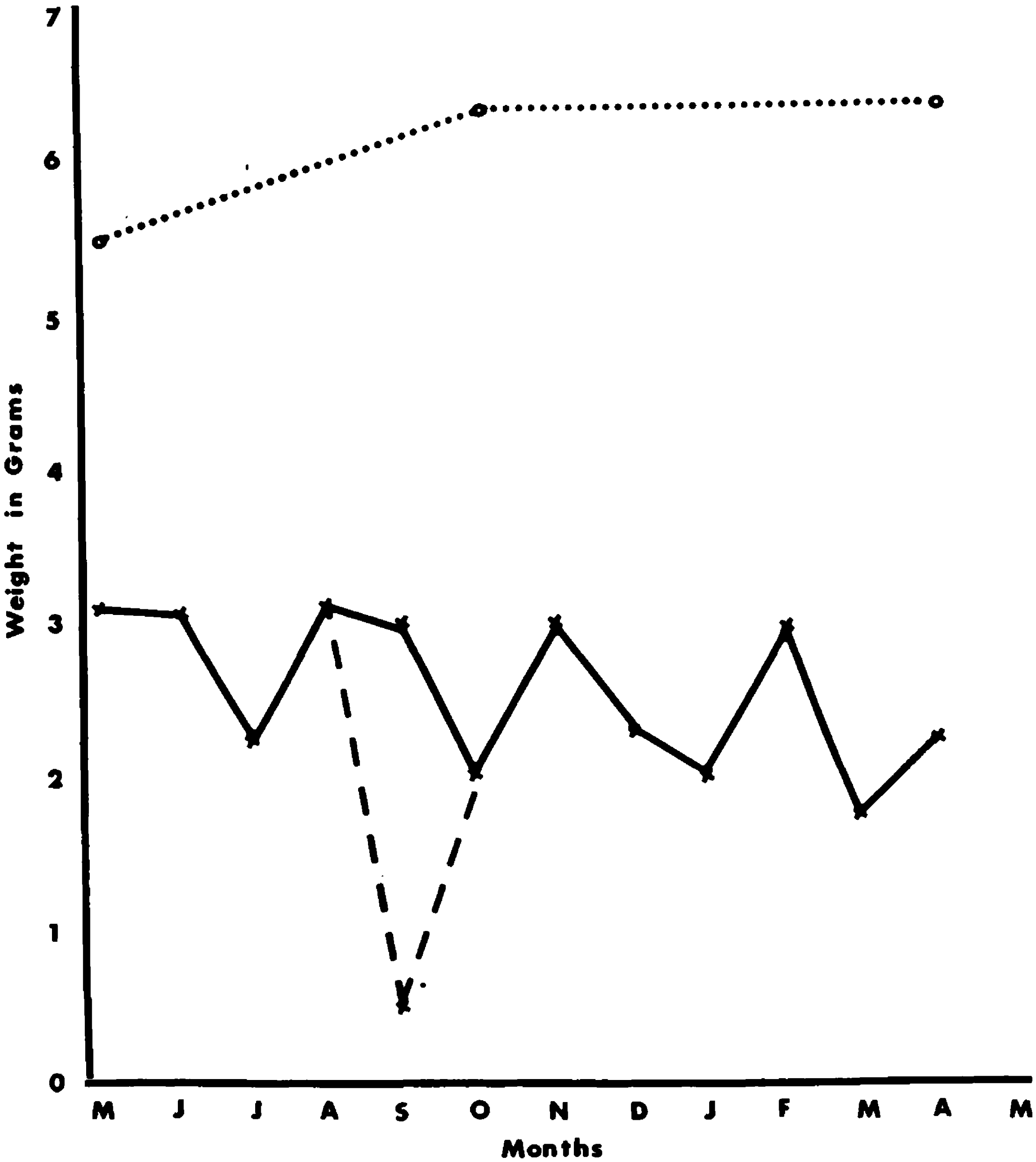
Body Weight per Unit Length

X——— Bison Range 1958- 59

X— — Bison Bange 1967 (ill)

o...... Rock Creek

Fig. 31. Adrenal weights of Rock Creek and Bison Range bighorn sheep.



Adrenal Weights

x——— Bison Range 1958–59

x— —Bison Range 1967 (ill)

o...... Rock Creek

Fig. 30, showing weight per unit length of the sheep, is presented as another index of condition. The results are nearly identical with those of the kidney fat index although of a lesser magnitude, and can be interpreted in the same manner as the kidney fat indices were.

We may conclude, therefore, that the Rock Creek bighorn sheep are in a highly stressed state and in generally poor physical condition when compared with a reasonably healthy population. The Rock Creek sheep are in such extremely poor condition in the early spring that the kidney fat index is zero. If bighorn sheep experience the same decrease in reproductive success and survival of young as deer on inadequate rations, particularly in the last one-third of gestation, the Rock Creek bighorn is not presently a very productive population (Verme, 1963; Thompson and Thompson, 1968, 1953, 1963).

Nutrition

Table 38 presents the daily nutrient requirements for domestic sheep and for deer. The figures for domestic sheep were obtained from the NAS-NRC (1964) report on the nutrient requirements of domestic sheep. The figures represent minimum "nutrient requirements sufficient to promote maintenance, optimum production, and prevention of all symptoms of nutritional deficiency, . . . under conditions of stress . . . a greater quantity of nutrients may be beneficial (NAS-NRC, 1964:1)." French, et al. (1956), found that requirements for domestic stock as determined by the NAS-NRC were close to those of the deer used in feeding trials. We will assume in this discussion that the same can be said for domestic and bighorn sheep.

The results of analyses of the major forage plants of the Rock Creek bighorn sheep are given in Table 39 and are summarized for bluebunch wheatgrass (the most important constituent of the diet) in Table 40. The chemical analyses of some other forage plants which are found in Montana, or which are germane to the consideration of the nutritional regime of the Rock Creek bighorn sheep are presented in Table 41.

Protein and Crude Fiber

The 4.3% level of protein found in the grass of Rock Creek does not approach most of the protein requirement estimates for domestic sheep and deer given in Table 38.

A critical consideration is the digestibility of these nutrients. If the sheep cannot utilize the nutrients which are found in the forage, nutritional deficiencies can result in spite of a seemingly adequate nutrient assay.

The digestion coefficients of protein in alfalfas for sheep and goats vary from 51-84% as reported by Schneider (1947). The lower coefficients are always from the more stemmy, mature feeds. The digestibility of protein found in the grasses of Rock Creek would be presumably lower than that of browse because of the lower protein and higher fiber content of the grasses. The crude fiber contents for Rock Creek grass during the winter and a representative sample of browse plants from other ranges are about 39% and 25%, respectively. This would compound the effect of the initially low protein level found in the grasses (about 4.3% for Rock Creek bluebunch wheatgrass and 8.2% for the browse found on other ranges). If the winter diet of the Rock Creek bighorn

Table 40. Summary of the chemical composition of bluebunch wheatgrass collected at Rock Creek

Plant	Season	% Crude Protein	% Ether Extract	NFE*	Ca:P	% Ash	% Crude Fibre	% Mg	% F	% Ca	mg/gms/lb Carotene	% K	% Mn
Agsp	Winter	3.90	2.71	46.09	1:1.0	6.57	39.19	.052	.059	.125	1.26	.084	.00690
Agsp	Spring (early)	4.72	2.46	44.20	6:1.0	8.42	39.78	.032	.074	.12	.95	.118	.0022
Agsp	Summer	5.4	3.3	39.20	9:1.0	11.1	32.0	.056	.10	.29	7.7	.83	.0046

*Nitrogen free extract.

sheep consists of about 90% grass at 4.3% crude protein, the remaining 10% browse and forbs consumed would have to consist of about 31% crude protein to bring the dietary crude protein to the 7% level recommended as a minimum maintenance requirement for deer (Table 38). The probability of the browse and forb portion of the diet being this high in protein is negligible (Knoche, 1968).

The protein deficiencies of an essentially grass diet are accentuated as the winter progresses. The animals occupy the winter range in October and leave it by June. As they use and reuse the grass, taking the more nutritious portions first, the nutritive quality declines.

Protein decreases to about 75% of initial levels as grass utilization reaches 50%. The reduction in protein would be proportionately greater at such sites as exclosure number 4 where utilization reaches 99%.

It appears that the protein level of the winter diet of these sheep is between 3 and 5%. Such a level of protein, in domestic sheep, results in a reduced appetite, lowered feed intake and poor feed efficiency, which, in turn, results in poor growth and muscular development, reduced reproductive efficiency, and other physiological maladies (NAS-NRC, 1964: 7).

Calcium and Phosphorus

Although most of the sedimentary soils of Montana are rich in calcium, exceptions have been noted in portions of the nearby Bitterroot Valley and in some of the high mountain valleys. Phosphorus deficiencies are typical in many portions of Montana, particularly in the high mountain valleys (Orcutt, 1953).

None of the Rock Creek samples meet the phosphorus requirements of about 0.2% P listed in Table 38, being on the order of only .0665% Phosphorus. The range plants sampled show a calcium level of about 0.122%--considerably lower than the level of about 0.25% recommended by the NRC (Table 38).

Rations which are deficient in calcium or phosphorus may result in the retardation of bone development. Phosphorus is required for the proper functioning of vitamins and enzymes. A deficiency, in domestic sheep, can result in slow growth, unthrifty appearance, listlessness, lack of body fat, weak lambs, decreased milk production, and, in deer, irregular ovulation (NAS-NRC, 1964:8; Swank, 1958:38).

The most desirable calcium-phosphorus ratio is 2:1 to 1:2, and not exceeding 5:1 (Dietz, et al, 1962:53). Our samples are within these limits.

Another possible effect of the very poor calcium and phosphorus levels found during the winter in the forages of Rock Creek is the reduction in skeletal development of the Rock Creek sheep discussed in the sections on inbreeding and growth. Aderhold (MS) believes that the bighorn sheep have resided in the Rock Creek area for over 4,500 years. Through processes of adaptation to chronic deficiencies of calcium and phosphorus, the bighorn sheep may have reduced their total requirement by a reduction in size, or altered their metabolism of calcium and phosphorus, or both. Alexander Ross, a trapper, was snowbound during the winter of 1823-24 in the vicinity of Sula, Montana, about 30 miles southwest of the study site. This area in the East Fork drainage of the Bitterroot River is linked to the Rock Creek area by the contiguous

Sapphire-Pintlar mountain complex. Ross' expedition survived by living on bighorn sheep, which, he reported, were very small, averaging 70 pounds total weight (Aderhold, MS).

Magnesium

Magnesium functions in enzyme systems associated with carbohydrate metabolism and in the proper functioning of the nervous system. Magnesium is closely associated with calcium and phosphorus metabolism. The magnesium levels of about .042% found in the Rock Creek forage do not meet the requirements of .06% considered adequate by the NAS-NRC (1964).

If a larger portion of the diet consisted of browse, the nutritional requirements for several of the deficient dietary items could be met. It is possible that the reason the deer have been able to survive and increase, while the bighorn has suffered such drastic declines in recent years at Rock Creek is the higher proportion of browse, particularly the nutritious, although not preferred, big sage (Table 41). As will be shown in the section on land use history, prior to the overgrazing of the early 1900's, the bighorn sheep were more numerous than the deer.

In sum, it appears that the nutritional plane of the Rock Creek bighorn sheep is deficient with regard to protein, calcium, phosphorus, and magnesium.

Horn measurements which were made on the Rock Creek bighorn rams indicate that prior to the present decline, horn growth was greater than during the beginning of the decline in 1965 (Fig. 4). Bighorn sheep experience their greatest horn growth during their second and third summers (Taylor, 1962:54). Fig. 4 indicates that the four-to-five-year-old sheep, secured for the most part during the 1967 and 1968 field seasons, showed a relatively small amount of annual horn growth for 1964 and 1965. The one- and two-year-old postdecline sheep have evidently not experienced any horn growth retardation. The older post-decline sheep, which had completed most of their horn growth before the 1965 die-off, show no significant difference in horn size from those which had died prior to the decline. Presumably, one can ascribe the decreased horn growth in the sheep which were two- to three-year-olds at the beginning of the decline, to poor nutrition on the winter range which resulted in poor physical condition in the summer.

The summers of both 1964 and 1965 broke records for their high rainfall and cool temperatures--conditions not conducive to a rapid recovery from the debilitated physical condition of the sheep on the winter range. The heavy rains which occurred in early June, 1964, can be expected once every 200 years. August, 1965, was the coldest ever observed in many areas of southwestern Montana (U. S. Department of Commerce - Weather Bureau Climatological Data, 1964, 1965). The apparent recovery in horn growth over the past two years is difficult to explain in light of the present poor nutritional regime on the winter range, unless the rapid and nearly complete die-off has released the remaining sheep from some forage competition.

Also, it is possible that there are two subpopulations, one resident (on the winter range) and one migratory, and that early horn samples were from the latter. Now, apparently, only the resident sheep survive. These sheep might be in better condition during the summer, not having just undergone the rigors of a migration, and probably have provided us with most of the specimens found on the winter range during the past two years. There is some evidence to support this postulate in that nearly all of the migratory sheep have disappeared from the population.

Another factor which influences nutritional requirements is the fluctuating metabolic demands made by changes in weather. Gerstell (1937) has shown that at temperatures of below 40° F., the weights in mature deer on adequate rations fluctuate with the temperature, and those on deficient feed lose weight. Below 30° F. the deer lost between three and 12 pounds per 100 pounds body weight regardless of the quantity or quality of the feed. The past winter with unusually low temperatures and high snow accumulation occurring in December and January could have aggravated the effects of an already low nutritional plane to facilitate the very poor condition found in the sheep during the early spring (Fig. 29).

Growth

Measurements of selected skull bones of the Rock Creek, Wildhorse Island, and Bison Range sheep are presented in Figs. 5 through 8, 32, 33, and Table 42. The following general conclusions may be drawn: 1) The Rock Creek population is significantly smaller than the other two populations based upon the coefficient of difference test applied to each population (Table 12). These characters reveal a greater difference in size than those used by Cowan to differentiate the recognized subspecies of <u>Ovis canadensis</u> (i.e., <u>Ovis canadensis canadensis</u> from <u>Ovis canadensis nelsoni</u> as given in Bradley and Baker, 1967).

2) The growth in females is most rapid during the first two years of life and levels off at about three and one-half years of age. This corresponds to the onset of reproduction.

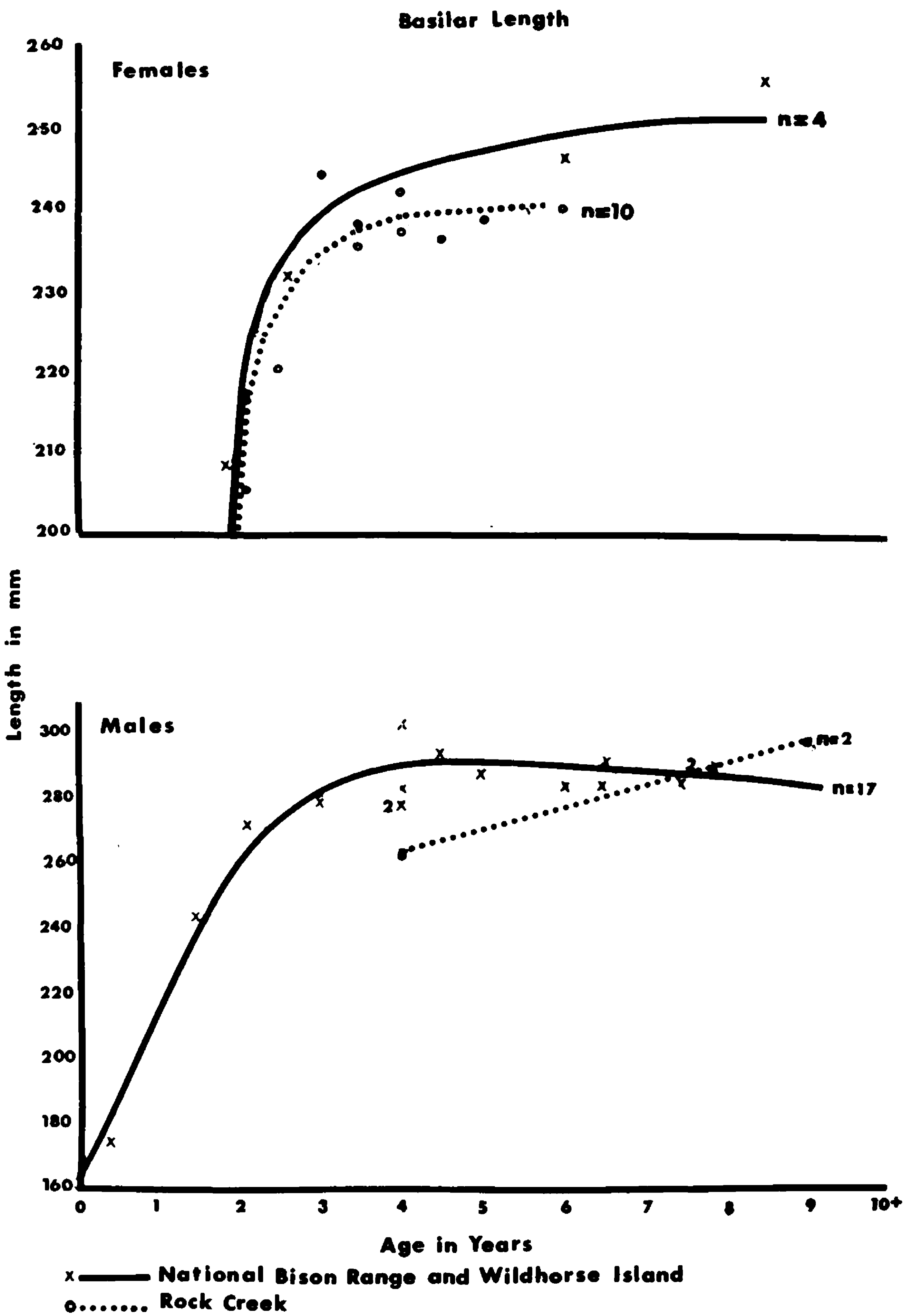
3) The growth of males begins to slow at about four years of age; however, in male Rock Creek sheep growth continues throughout the adult years considered in the measurements (to nine years of age) at a greater rate than found in females.

4) Growth and size patterns are similar for each of the characters measured.

5) Males can be distinguished from females on the basis of skull measurements by one and one-half years of age.

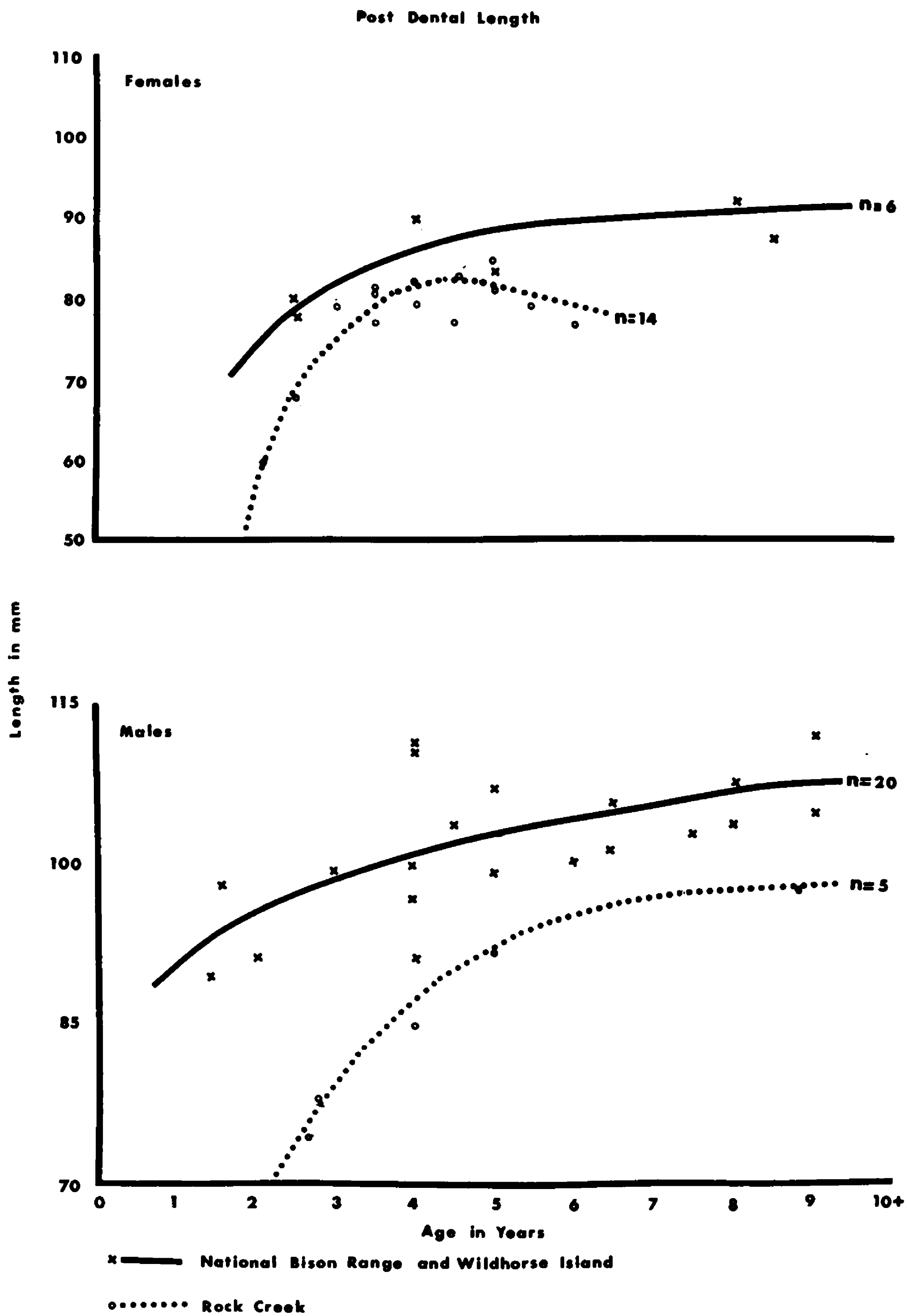
6) Lamb and yearling age classes can be distinguished from the older animals on the basis of the skull measurements. By about two years of age overlap with the measurements of older animals begins to occur.

Fig. 5. Comparison of basilar length growth rates for Rock Creek, Bison Range, and Wildhorse Island bighorn sheep.



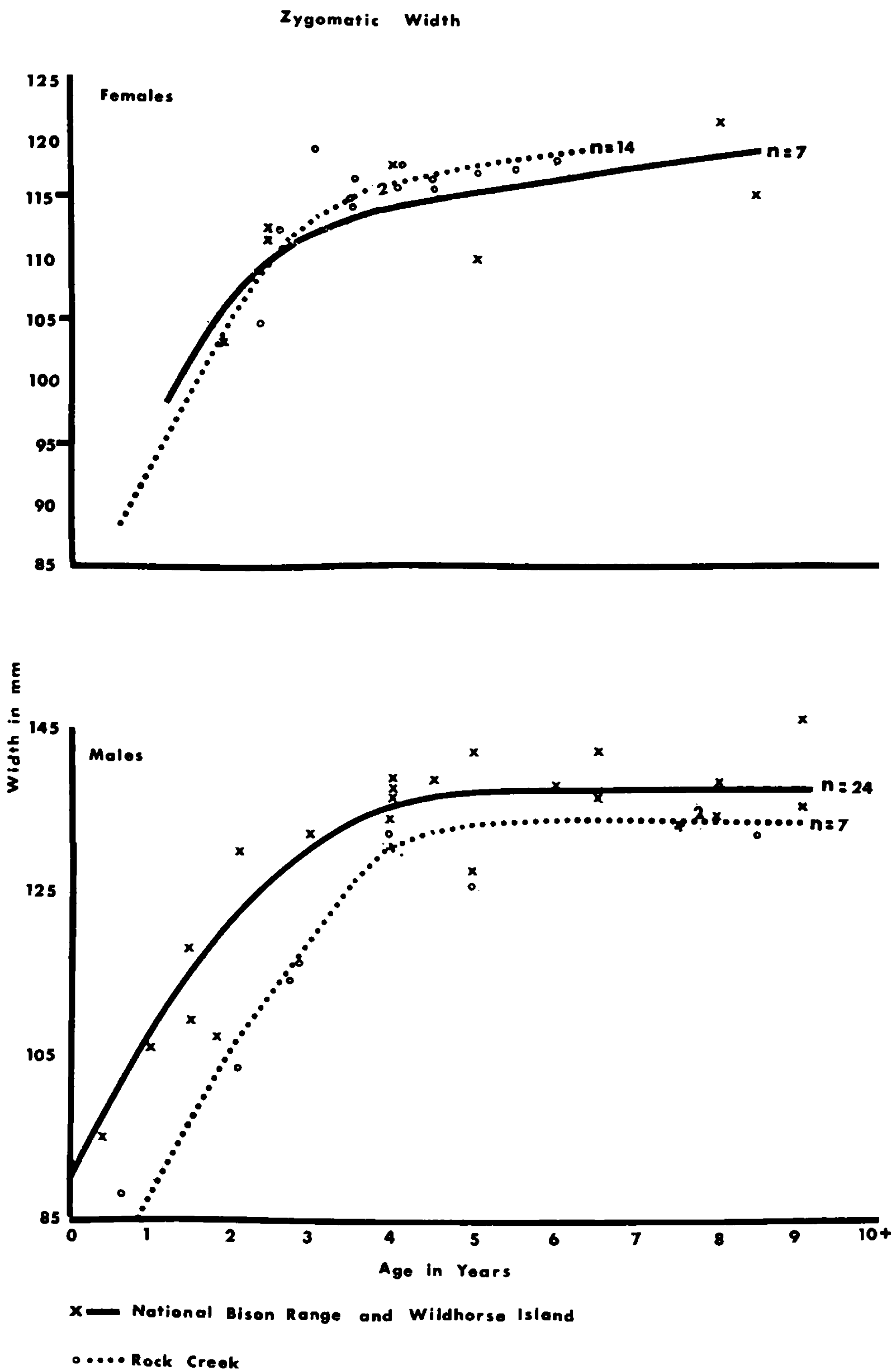
Basilar Length
Females
n=4
n=10
Males
n=2
n=17
Length in mm
Age in Years
National Bison Range and Wildhorse Island
Rock Creek

Fig. 6. Comparison of postdental length growth rates for Rock Creek, Bison Range, and Wildhorse Island bighorn sheep.

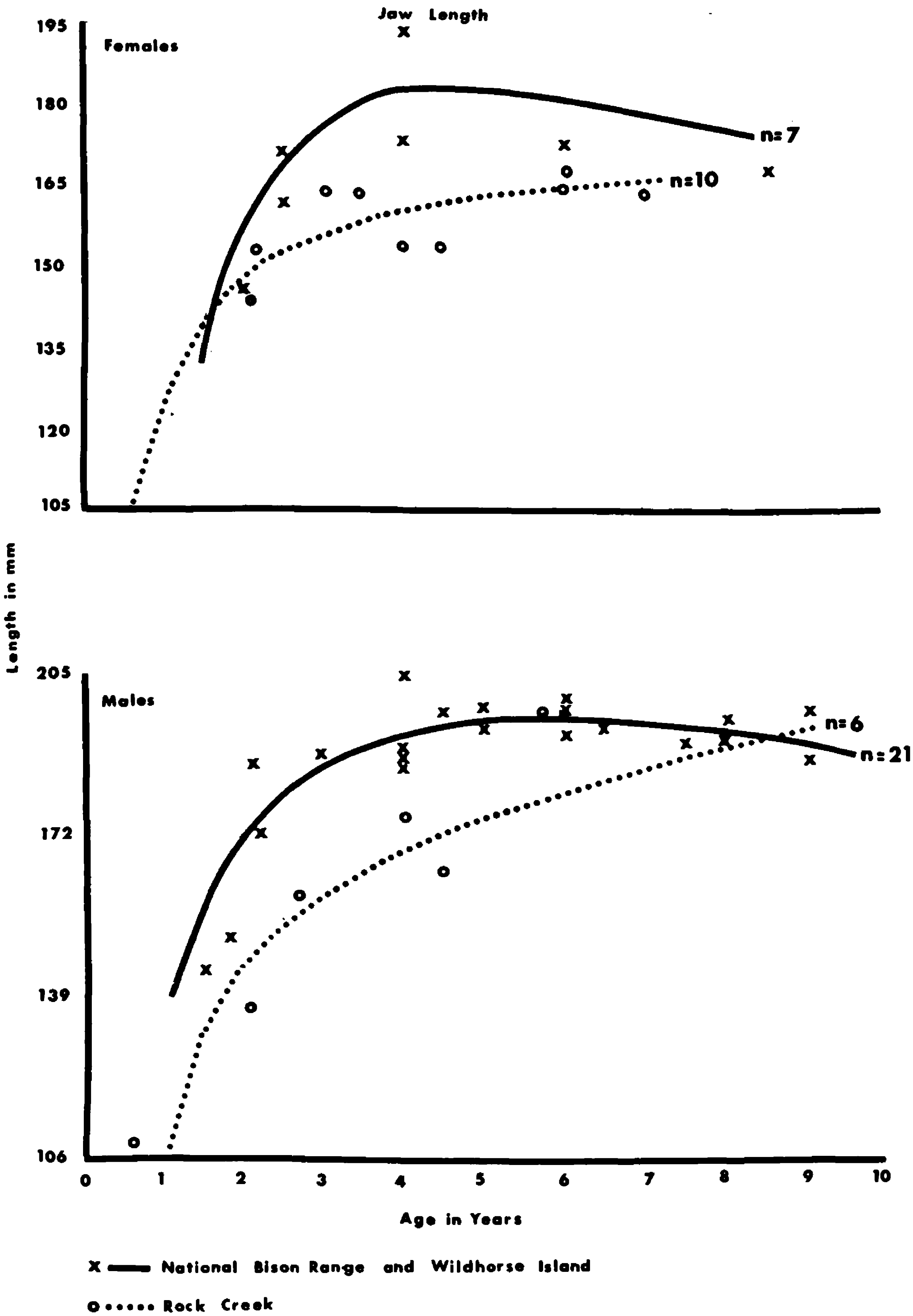


Post Dental Length
Females
Males
Length in mm
110
100
90
80
70
60
50
115
100
85
70
n=6
n=14
n=20
n=5
0
1
2
3
4
5
6
7
8
9
10+
Age in Years
National Bison Range and Wildhorse Island
Rock Creek

Fig. 7. Comparison of zygomatic width growth rates for Rock Creek, Bison Range, and Wildhorse Island bighorn sheep.



Zygomatic Width
Females
125
120
115
110
105
100
95
90
85
n=14
n=7
2
Width in mm
Males
145
125
105
85
n=24
n=7
2
0
1
2
3
4
5
6
7
8
9
10+
Age in Years
X National Bison Range and Wildhorse Island
o •••• Rock Creek


Jaw Length
Females
195
180
165
150
135
120
105
n=7
n=10
Length in mm
Males
205
172
139
106
n=6
n=21
0 1 2 3 4 5 6 7 8 9 10
Age in Years
X National Bison Range and Wildhorse Island
O Rock Creek

PART VI: LAND USE PLANS FOR THE ROCK CREEK AREA

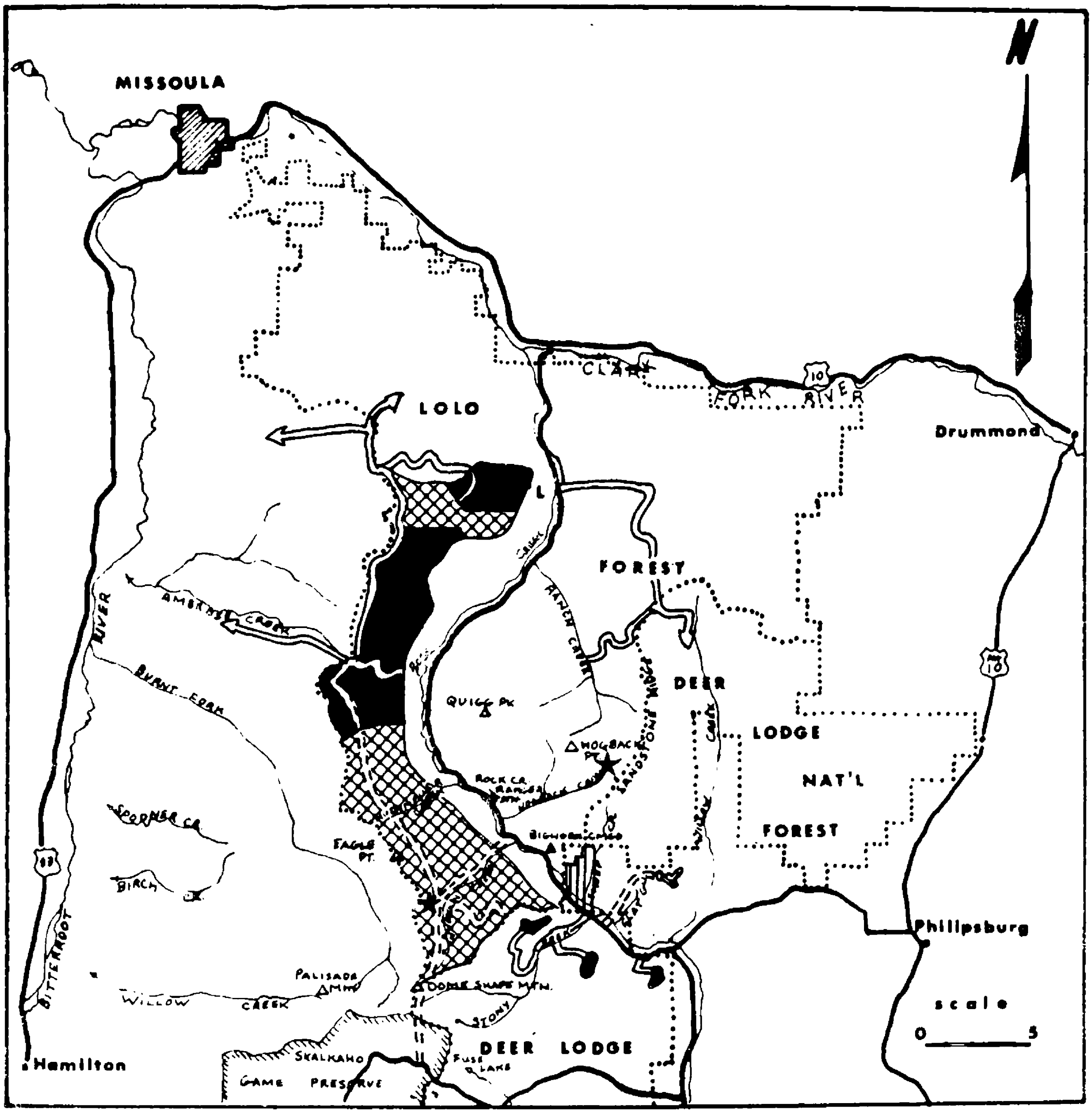
Plans for the utilization of the timber, mineral, and recreational resources of the Rock Creek area portend considerable ecosystem alteration which could have a great impact on the wildlife of the study site.

Fig. 39 details the current and projected major commercial activities in the area. These are: 1) the subdivision and sale of the Boomer-Brewer ranch primarily for seasonal recreational use; 2) the current logging, in clear cuts, of about one-third of the Rock Creek drainage below the Sapphire Crest; 3) the proposed sale of the remainder of the timber along the Rock Creek drainage below the Sapphire Crest; 4) the proposed construction of access roads to these timber sales, the major access being provided by a road euphemistically called by the Lolo National Forest staff the "Sapphire Scenic Route"; 5) a small timber sale northeast of the winter range with access to be provided by a proposed road up Flat Gulch; 6) a stream survey of Rock Creek from Bighorn Campground to its mouth; 7) two packer camps on either side of Rock Creek which are used during the hunting season; 7) inventories of game ranges in the Lolo National Forest lands in the area; and 8) mineral surveys by the Bear Creek Mining Company. Details presented in Fig. 39 were gathered by ranger Hoke Grotbo of the Deer Lodge National Forest ranger station at Philipsburg.

An extensive timber harvest is planned and in progress along the Rock Creek drainage of the Sapphire crest. At present the timber sales and associated logging roads have reached the reported boundaries of the bighorn summer ranges (Figs. 9 and 39). Proposed timber sales will result in road construction and logging activities throughout the now

Fig. 8. Comparison of jaw length growth rates for Rock Creek, Bison Range, and Wildhorse Island bighorn sheep.

Fig. 39. Land use plans for the Rock Creek area.



Current:

- Timber sales
- Packer camps
- Logging roads

Proposed:

- Timber sales
- Logging roads
- Private land sales
- Stream survey

virgin forest in which the sheep have reportedly summered. The timber will be harvested in a series of clearcuts which travelers will be able to view from the "Sapphire scenic" route which will run along the divide and provide access to the logging areas. Little additional game range will be created by this logging. The slopes are heavily forested down to Rock Creek and are blanketed by deep and persistent snow throughout the winter in contrast to the hillsides on the opposite side of the creek which constitute the bulk of the winter ranges. The effects of these timber sales on wildlife and the water regime of the blue-ribbon fishery of Rock Creek are difficult to predict.

A small timber sale is proposed by the BLM for the Miner's Gulch area directly in back of (north) the bighorn sheep winter range. An access road which will bisect the present bighorn and mule deer winter range by ascending Flat Gulch is planned and will, if constructed, lead to the extirpation of bighorn sheep on this winter range.

Logging operations are in progress on the slopes which face the winter range and have generally increased the traffic and activity adjacent to the present winter range. These sales amount to about 15 million board feet of primarily Douglas fir. A 5.5 mile access road up Cornish Gulch, opposite the Neal ranch, has been completed this spring at a cost of about $55,000. Once these roads are built, current policy dictates their maintenance, apparently in perpetuity, precluding any future considerations of such bighorn management practices as transplanting.

A recreational development plan for the Lolo National Forest is currently being drawn up and should considerably affect access and visitor use along Rock Creek. Related to this are plans for the construction of a new, larger bridge across the Clark Fork River at the mouth of Rock Creek and the purchase of right of way for road development on the Puyear ranch at the southern boundary of the present winter range. The end result will likely be a considerable increase in traffic and general use by recreationists.

Extensive surveys of the entire Rock Creek drainage north from the southern extreme of the winter range have been conducted by the Bear Creek Mining Company of Spokane, Washington, during the last two years. Plans for the development of the mineral resources are not known at this writing.

The Rock Creek Valley, from its mouth to about ten miles upstream, has recently been the site of considerable speculation in real estate. Larger holdings are being purchased and subdivided into small land two acre lots to be sold for summer homesites.

We can expect the demand for property for recreational purposes and the appreciation of property values to continue. Rock Creek, in addition to its inherent recreational attractions is nearly equidistant from two of the largest urban areas of Montana. Missoula (population about 40,000) and the Butte and Anaconda complex (combined population of about 66,000) are 59, 62, and 42 miles away, respectively. The population of nearby urban areas is increasing at a steady rate. For example, Missoula County with a population of 35,493 in 1950 and 44,663 in 1960, has a projected population of 58,324 for 1970 according to W. D. Diehl of the Bureau of Business and Economic Research at the University of Montana (<u>pers</u>. <u>comm</u>.).

An interesting and important influence on the land use changes and the policies of the custodial agencies whose responsibilities encompass the wildlife resource of Rock Creek, is the attitude and activities of local, often vocal, sportsmen's organizations. During 1960 and 1961 the State Department of Fish and Game had the opportunity to purchase an extensive and vital portion of the Rock Creek winter range. The Department showed considerable interest in the purchase and evidently had gone so far as to allocate the necessary funds (Fred Hartkorn, pers. comm.). The Anaconda Sportsmen's Club offered considerable resistance to the purchase, feeling that (paraphrasing) it was more desirable to shoot a deer once a year than risk a decrease in deer hunting through management policies oriented toward bighorn sheep (which a hunter may shoot once every seven years in Montana).

Because of the question of local opposition to any set of priorsities which might decrease the sum meat yield during a hunting season, I have attempted to characterize a bighorn sheep hunter and to clarify the value of the Rock Creek sheep herd to the local economy. A questionnaire was mailed to all successful permittees since 1954 (Appendix G). I mailed about 70 questionnaires and had 30 respondents. This was a good return since about 20 letters were sent to addresses from which the hunter had moved. Table 44 indicates that bighorn sheep hunters do not resemble, for example, the average deer hunter in the time spent hunting or the species of game harvested.

The average expenditure amounted to $10.30 a day and the average hunt lasted seven and one-third days. Therefore, each hunter spent an average of $75 for his sheep at Rock Creek.

Table 44. Per cent of Rock Creek sheep permittees which have shot various species of big game (before and after Rock Creek hunt)

Deer	Elk	Moose	Goat	Caribou	Sheep	Bear	Antelope
100	96	58	54	12	27	58	27
34*	38*	4*	2*	2*	2*	12*	19*

*Indicates largest number per person.

Table 45. Dollars spent each day of hunt (by per cent respondents)

Dollars	0-5	5-10	10-20	20-30	30-50
%	20	48	24	4	4

There have been 84 permittees of which about 76% were successful. About 8% of the sheep shot were females. The 84 hunters spending about $75 a hunt would have spent about $6,300 in the area. Other studies have indicated that hunters considerably underestimate their expenditures (Taber, <u>pers</u>. <u>comm</u>.) and I feel that these figures should, in fact, be higher.

An encouraging innovation in the concept of game management on an area such as the Rock Creek study site, began with the first meeting of the "Interagency Committee" for the management of game on management unit 210, which includes Rock Creek. The committee consists of representatives of the Montana Fish and Game Department, the Bureau of Land Management, the U. S. Forest Service, local landowners, and the University of Montana. Recognizing the necessity of effective communication between people and agencies whose policies bear directly upon the well-being of the wildlife resource whose movements and biology do not always coincide with the complex political boundaries of a winter range, the committee will serve to: 1) collect existing data relevant to the management of game in the area of the bighorn sheep study site; 2) formulate and implement a resource inventory program; 3) formulate and implement a game management program; and 4) conduct an information and education program to support its recommendations. The committee concept, if successful, is envisioned by the representatives as serving as a pilot program for the management of other game ranges throughout the state. The committee was formed, in part due to the impetus provided by the present investigations of bighorn sheep in the management unit. Programs being planned after three meetings could have a considerable impact upon the future of the Rock Creek bighorn winter range.

PART VII: SUMMARY

A study of the factors limiting the Rock Creek, Montana, population of bighorn sheep began in December, 1966, and was completed in April, 1968. Data were collected which characterized the floristic composition, production, and utilization of the range resource and the competition for forage among the ungulates occupying the winter range. Observations of total numbers, sex, and age classes, distribution, movements, daily routine, and interactions of the bighorn sheep were made. The incidence of disease, parasitism, predation, and other mortality factors are discussed. The effects of inbreeding are considered. Data pertaining to the physical condition, nutritional plane, and rate of growth of the Rock Creek bighorn sheep are compared with other bighorn sheep populations found in western Montana. A history of the effects of the cultural practices of man was evaluated in light of the present status of the bighorn sheep. The results of the investigations considered in this paper are summarized below:

1) Prior to the extensive settlement of the area by modern man, bighorn sheep were more plentiful than mule deer. Now there are about 70 mule deer for each bighorn.

2) About 150-200 bighorn sheep occupied the winter range prior to 1965. A population decline began in 1965, and currently there are 15 sheep that use the winter range.

3) Inbreeding in the Rock Creek bighorn sheep occurs at a rate which could lead to a decrease in vigor, and reproductive success and the significantly smaller size of the Rock Creek sheep when compared to other populations of the same subspecies.

4) Extensive changes in the ecosystem of the Rock Creek winter range, such as the elimination of the natural predators of the game animals, the reduction and elimination of the more preferred and nutritious forages, and the restriction of the grasslands by the invasion of timber and less valuable shrubs, has resulted from such cultural practices of modern man as overgrazing, large predator control, and fire suppression.

5) Natural predation of the Rock Creek bighorn sheep is negligible.

6) Sheep movements to and from summer ranges have been nearly eliminated by the selective mortality of the migrant sheep above that of the year-round resident sheep.

7) Sheep movements occur in patterns on the winter range which primarily reflect local differences in plant phenology, mineral licks, and the availability of cover during periods of inclement weather.

8) A total loss of the older rams has occurred.

9) Extensive overgrazing of the northern portion of the winter range, and the loss of the leaders of the ram groups has nearly resulted in the abandonment of the northern portion of the winter range which, prior to the decline, supported about 20% of the bighorn population.

10) The average group size of Rock Creek bighorn sheep is about one half that of other populations.

11) The open timber type, with a bunchgrass understory, is important as a feeding and bedding area during periods of inclement weather and snow accumulation.

12) The range is generally overgrazed and is rated as being in fair condition. About 24% climax plant species (decreasers) are found.

13) The areas in which the bighorn sheep concentrate are in a higher seral stage than the rest of the range with about 50% of the plants classified as decreasers.

14) The range trend is generally down at a very slow rate.

15) Utilization of grasses range from about 40%-99% and results in much more grazing pressure than the range resource can bear.

16) The most intensive competitor for forage with the bighorn sheep is the mule deer. Seven to eight hundred occupy the winter range with about 400 deer inhabiting areas on which the bighorn sheep concentrate. Grasses constitute about 90% of the diet of the bighorn sheep and about 40% of the diet of deer during a normal winter. At present stocking rates, about 210 deer would have to be removed to allow the range to recover. To achieve a predecline population of 200 bighorn sheep, about 269 deer would have to be removed.

17) The annual physical condition of the Rock Creek bighorn sheep is lower than that of the sheep of the National Bison Range. The Rock Creek sheep are in such extremely poor condition in early spring that the kidney fat index is zero.

18) The Rock Creek bighorn sheep exist in a chronic highly-stressed state.

19) The diet of the sheep is unable to provide minimum maintenance levels of protein, phosphorus, calcium, and magnesium due primarily to the virtual absence of the preferred species of more nutritious browse plants found on other winter ranges in western Montana.

20) Reproduction is low due to mortality of ewes and fetuses prior to lambing.

21) The adult ewes are particularly vulnerable to heavy mortality during the summer.

22) Most mortality occurs during the summer.

23) Lamb losses are 85-90%.

24) Lungworm is not an important factor in the decline of the Rock Creek sheep.

25) Harrassment of the sheep by recreationists and, in particular, by dogs owned by residents living adjacent to the winter range is extensive.

26) Several of the proposed timber sales and access roads will be detrimental to the bighorn sheep.

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APPENDIX A

MONTANA COOPERATIVE WILDLIFE RESEARCH UNIT
University of Montana
Montana Fish and Game Commission
Wildlife Management Institute
Fish and Wildlife Service, United States Department of the Interior

University of Montana

Missoula, Montana 59801

Dear Mr.

The Rock Creek, Montana, bighorn sheep herd which has provided you and about 70 other sportsmen with a trophy and many hours of high quality hunting has recently experienced a dramatic decline in numbers.

Two years ago the University of Montana in cooperation with the Montana Department of Fish and Game and the Montana Cooperative Wildlife Research Unit began an intensive study of the Rock Creek sheep. A portion of this study includes a comparison of growth rates and horn structure with other sheep populations. The measurements requested below will provide assistance in this phase of the study.

To better assess the recreational and economic value of the bighorn sheep, we have requested information regarding the hours and money you spent in pursuit of your trophy.

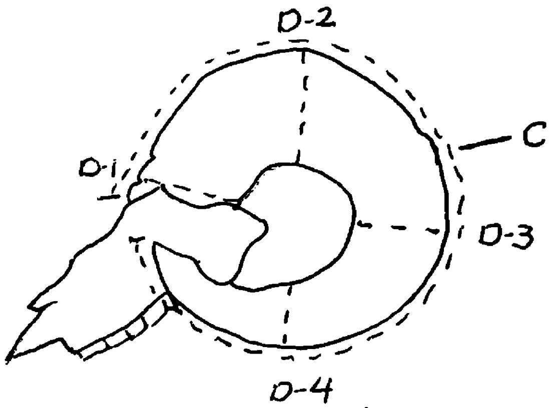
Also, any additional information you think would aid the study, such as acts of predation, heavy parasitism, condition of the carcass, etc., would be appreciated.

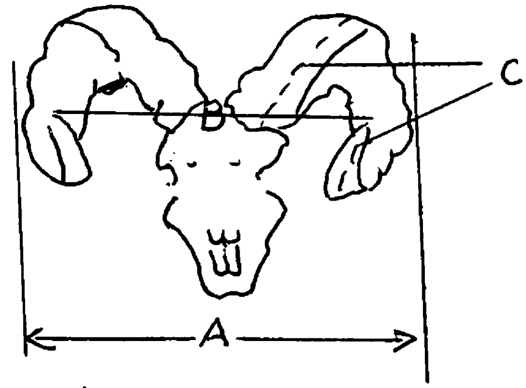
Thank you,

Stephen Berwick
Department of Wildlife Management
School of Forestry
University of Montana

1. Age of sheep _______
2. Estimate of herd size _______
3. Largest number of sheep seen on a single day _______
4. Largest number of rams seen on a single day _______

5. Horn measurements





A. Greatest spread (often tip to tip spread) ______

B. Tip to tip spread (if same as "A" enter again) ______

	Right	Left
C. Length of horns	______	______
D. 1. Circumference at base	______	______
2. Circumference at first quarter	______	______
3. Circumference at second quarter	______	______
4. Circumference at third quarter	______	______

6. Number of years of big game hunting previous to sheep hunt ______

7. Have shot: (check)

	Previous to sheep hunt	Since sheep hunt
deer	______	______
elk	______	______
moose	______	______
caribou	______	______
goat	______	______
sheep	______	______
bear	______	______
cat	______	______
other	______	______

8. Days spent hunting ______

9. Estimated dollars spent per day sheep hunting:

0 - 5 ______	20 - 30 ______
5 - 10 ______	30 - 50 ______
10 - 20 ______	50 plus ______

10. Any unusual or noteworthy observations.

11. Other remarks. (use other side if necessary)

Coll. No. ______________ Species ____________________ Sex ____________

Age ______________ Time of Coll. ____________________ Date ____________

Area of Coll. ____

Circumstances of Death ____

Total Wt. ______________ Body Length ______________ Hind Foot ________

Heart Girth ____________________ Girth at Base of Neck ______________

Neck Girth at smallest point __________________

Wt. of Digestive Tract _______ Coll. Rumen Sample ______ Coll. Fecal

Sample ______

Coll. Blood Serum ________________ Coll. Whole Blood __________________

Wt. of Reproductive Tract ____

Fetus or Embryos ____________ C-R length ____________ weight ___________

Sex _________ Age __________ Organ weights ____________________________

Kidney Wt.________ w/fat________ w/o fat________ Spleen wt.____________

Adrenal wt.________ Liver wt.________ Liver vol. ______________________

Liver pathology ____

Heart wt._________ w/fat_________ w/o fat_________ sample of ___________
(remove blood clots) heart fat

Gross Pathology ____

Thyroid wt. ____________________ Thyroid vol. __________________________

Carcass wt. (Hog Dressed)_________________ Dressed Carcass wt.__________

Collect Jaw____________________

Results of Blood Analysis

Coll. No. ____________

Disease

Leptospirosis ______ Brucellosis ______ Anapolamosis ____________

Hematocrit _________ Red Count _________ White Count ______________

Polymorphs _________ Lymphocytes _________ Monocytes_________

Eosinophylls _________ Calcium _________ Phosphorus _________

Carotene _________ Vitamin A _________ Serum Protein ______________

Blood Sugar ___________________________ Save serum for later analysis

____

Results of Rumen Analysis

% Browse _________% Forbs _________% Grass-like _________%

Conifer _________%

Detailed Results: ____

BIGHORN SHEEP ECOLOGY INVESTIGATIONS FIELD CLIMATE DATE FORM

SNOW:

Station #_____ Area____________________ Date_________ Time________
Position

1 _____

2 _____

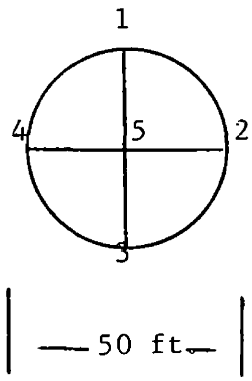
3 _____

4 _____

5 _____

Total _____

Mean _____



Snow Designation:
- new _____
- wet _____
- dry _____
- windpack _____
- corn _____
- slush _____

Snow Crust:
- breakable _____
- unbreakable _____
- variable _____

TEMPERATURE: ______

SLOPE: ^{o}azim. _____% _____

WIND: Instant. wind vel.(m.p.h.) - max._____ min._____
Average vel. _____
Wind direction _____
Wind characteristics ____

____

RELATIVE HUMIDITY: _____

COMPUTED EFFECTIVE TEMPERATURE: ______

BIGHORN SHEEP ECOLOGY INVESTIGATIONS WEATHER DATA FORM

Area ______________________ Station ______________________

Month ______________________ Observer ______________________

Current Weather ____

____

Time Date	Max.F	Min.F	Current F	Mean F	Comments

BIGHORN SHEEP ECOLOGY INVESTIGATIONS DATA SHEET FOR IMMOBILIZATION AND MEASUREMENTS

Animal No. ______

Sex ______

Age ______

Weight ______

Drug ______

mg. ______

mg/lb ______

Resp. rate ______

Heartbeat ______ (1 min.)

Weather conditions
Temperature ______
Wind ______
Humidity ______

Date ______

Area captured ______

Initial capture ______ Recapture____

Injection site ______

Immobilized ______

Reflex action ______

Comments:

MEASUREMENTS

Sex ______ Age ______

Weight ______

Total length ______ Hind foot ______ Neck at smallest circum. ________

Tail ______ Chest girth ______ Ear ______

Blood samples: Whole ______ Serum ______

Ectoparasites:

Mucus sample ______

Neck band number and color code: ______

Comments on appearance and condition:

Forage from mouth ______

Radio transmitter ______

APPENDIX B

Fig. 1. View of the study area showing interspersion of habitat types.

Fig. 18. Photo of clip plot.

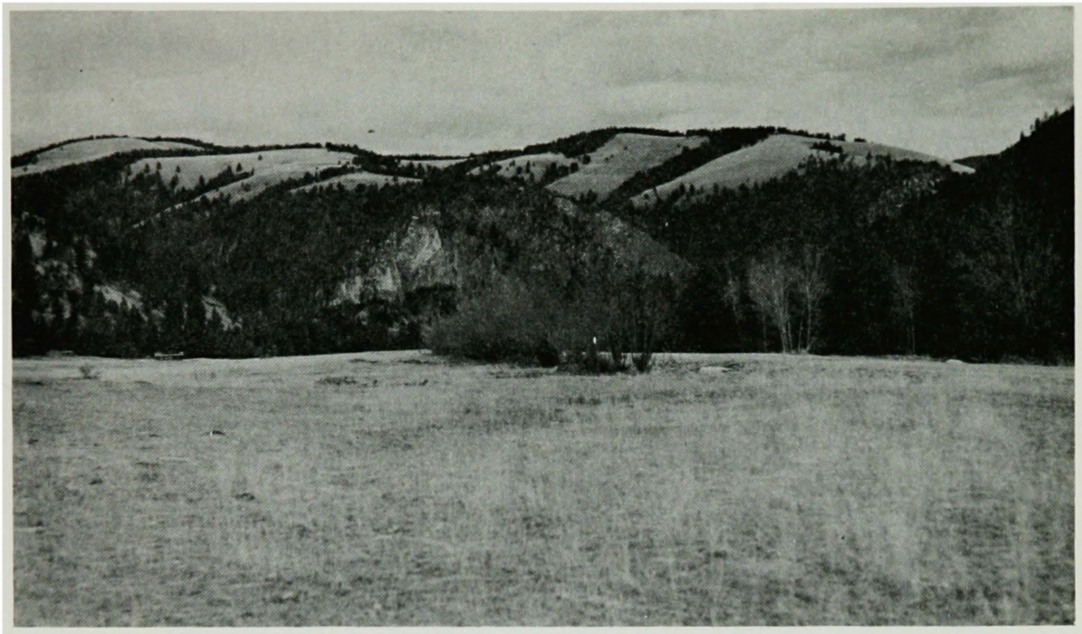
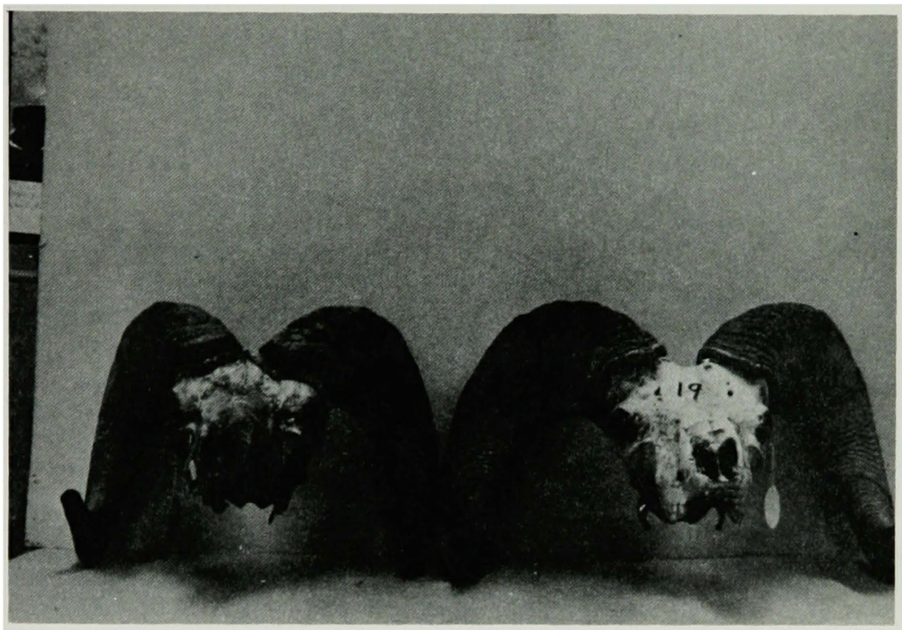


Fig. 32. Comparison of horn size and configuration of eight-year males from Rock Creek and Wildhorse Island.

Fig. 33. Comparison of jaw lenghts of four-year males from Rock Creek and the National Bison Range.


19

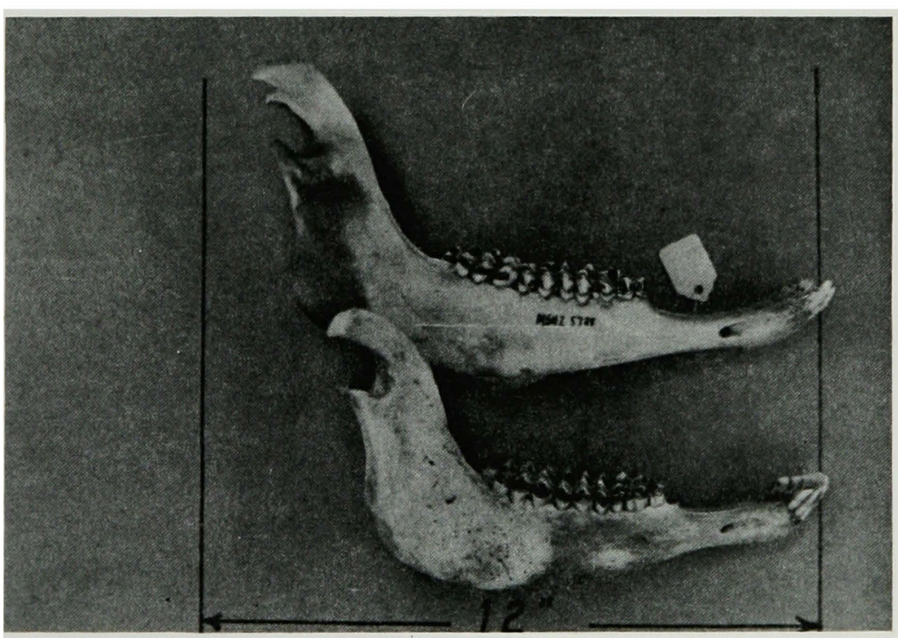
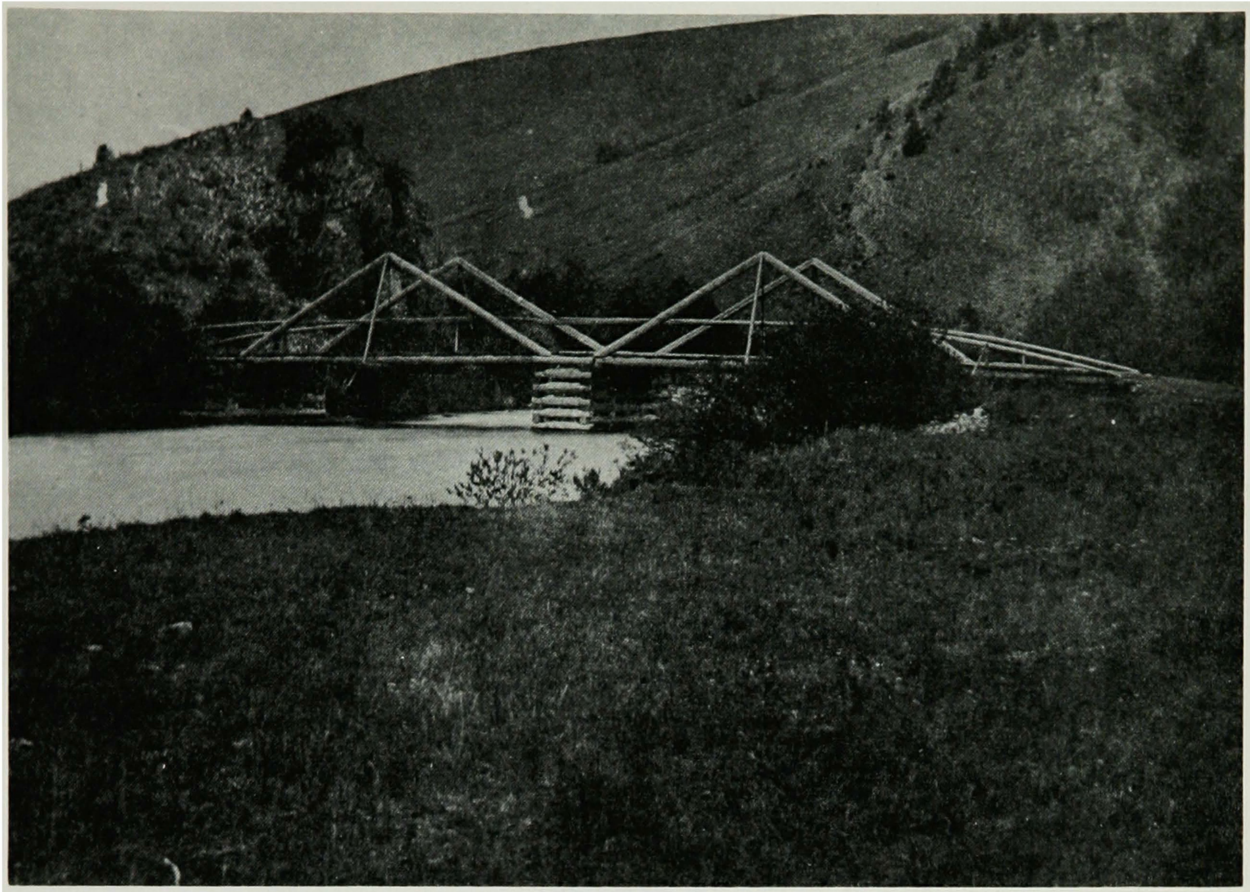
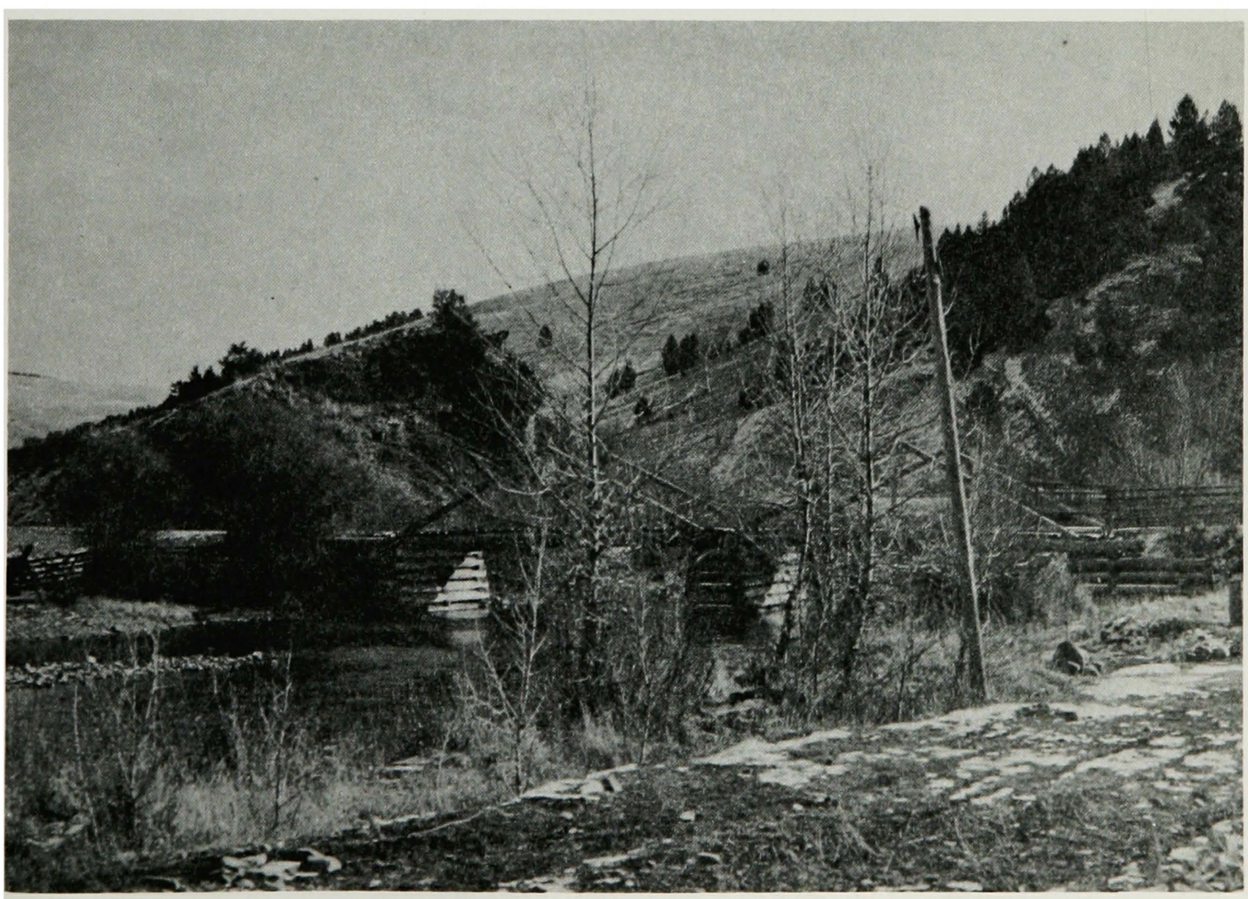

12"

Fig. 35. Tree distribution looking east from the Gillis bridge - about 1890.

Fig. 36. Tree distribution looking east from the Gillis bridge - 1968.





APPENDIX C

Table 9. Tick paralysis results (from Aderhold, MS)

Species	Source	Number of ticks	Number of hamsters	Results
andersoni	Boomer ranch	19	3	no paralysis
andersoni	Capron creek	17	3	no paralysis
andersoni	Jimmy Leaf	6	2	no paralysis
andersoni	Dead at Sheep Gulch	17	2	no paralysis
albipictus	Sheep Gulch Flagging	70	11	2/11 show tick paralysis
albipictus	Sheep Gulch Flagging	101	10	1/10 show tick paralysis
albipictus	Dead at Sheep Gulch	43	5	4/5 hamsters died: an anerobe was isolated from 2

APPENDIX D

Table 11. Horn measurements of sheep found or shot at Rock Creek*

Age	Birth	Death	Max Spread	Length	Basal Circ	1	2	3	4	5	6	7	8
4	1950	1954	16 4/8	28 4/8	13 4/8	2 3/8	9 7/8	6 6/8	5 6/8				
4	1950	1955	17	29 4/8	15 4/8								
5	1953	1958	12 4/8	27 4/8	10 2/8								
9	1951	1960	14 4/8	32 4/8	13 4/8								
4	1956	1960	17	31	14								
12	1949	1961	17 4/8	35 7/8	15 2/8								
8	1953	1961	18	30 4/8	14								
5	1956	1961	15 4/8	25 4/8	13								
12	1950	1962	18	30	14								
5	1957	1962	17 4/8	26 6/8	13 2/8								
5	1957	1962	17 5/8	28 7/8	13 2/8								
3	1959	1962	12 4/8	21	12								
2	1960	1962	13	14	9								
2	1960	1962	13 4/8	14	9 4/8								
5	1958	1963	16	25 5/8	14								
7	1958	1965	16	27	13								
4	1962	1966	13	22	12 4/8								
2	1963	1966	15 1/8	15 6/8	9 6/8	3	7 6/8	5 4/8					
2	1963	1966	16	16 4/8	9 2/8								
8 3/4	1959	1967	17	29 6/8	13	2 6/8	6	5 1/8	4 6/8	3 1/8	2 5/8	2	1 4/8

*Date from sheep killed during hunting seasons has been obtained primarily from questionnaires and in some cases by interviews and measurements by the author.

APPENDIX E

Fig. 19. Range studies--selection of exclosure plots for clipping.

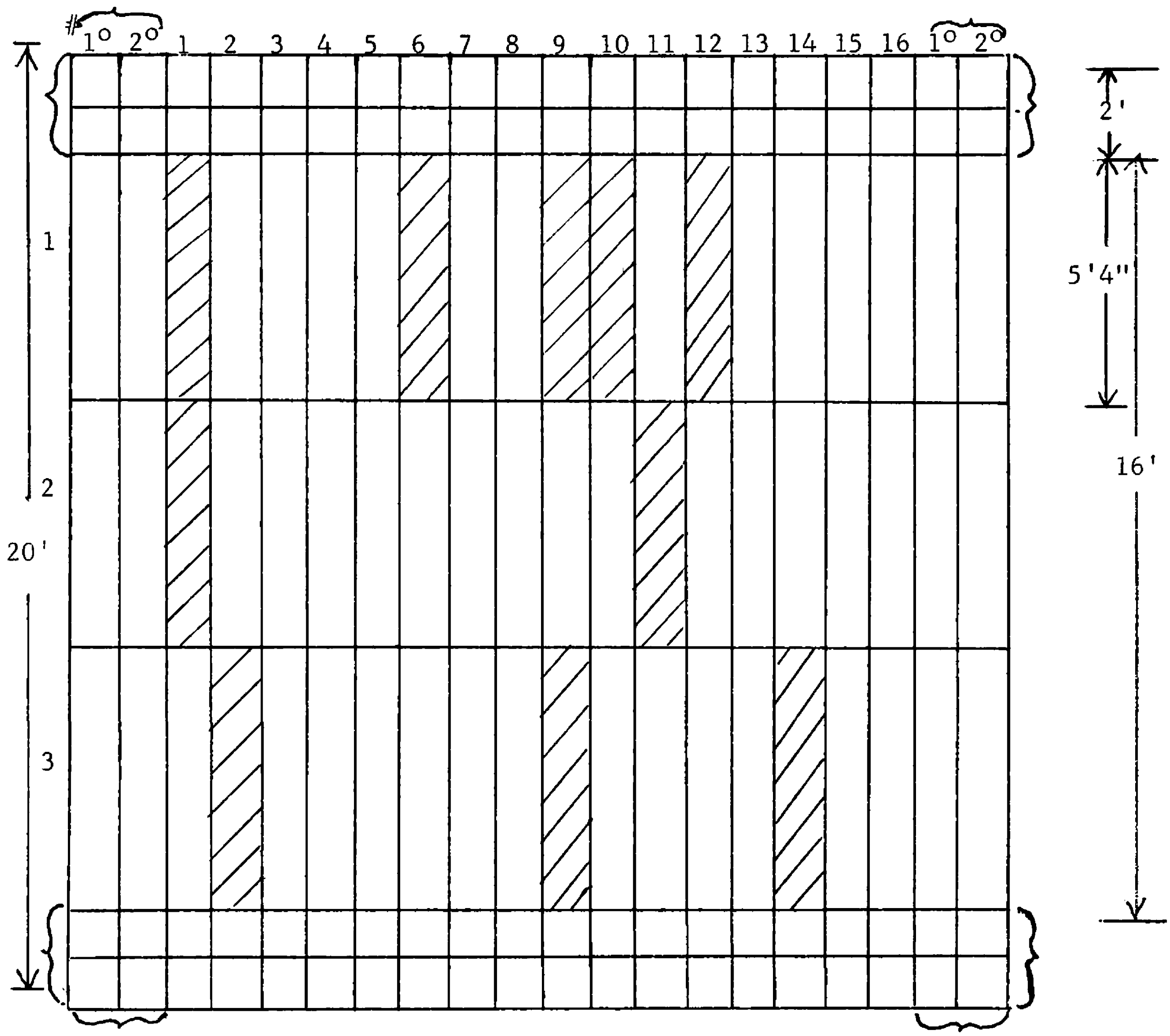

#
1° 2° 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 1° 2°
1
2
3
20'
2'
5'4"
16'

Table 20. List of the plant species found on the winter range*

SCIENTIFIC NAME	COMMON NAME
Forbs	
Liliaceae	
Allium cernum	Nodding Onion
Fritillaria pudica	Yellow-bell
Zygadenus elegans	White Camus
Zygadenus paniculatus	Death Camus
Polygonaceae	
Eriogonum spp.	Eriogonum
Polygonom douglasii	Douglas Knotweed
Chenopodiaceae	
Monolepis nuttliana	Nuttall Monolepis
Portulacaceae	
Lewisia rediviva	Bitterroot
Caryophyllaceae	
Arenaria congestis	Ballhead Sandwort
Cerastium arvense	Field Chickweed
Ranunculaceae	
Anemone patens	Pasque Flower
Delphinium bicolor	Low Larkspur
** *Thalictrum fendleri*	Meadow Rue
Berberidaceae	
Berberis repens	Oregon Grape
Cruciferae	
Arabis holboellii	Holbeoll Rockcress
Arabis microphylla	Littleleaf Rockcress
Camelina microcarpa	Littlepod Falseflax
Capsella bursa-pastoris	Shepherd's Purse
Conringia orientalis	Haresear Mustard
Descurainia pinnata	Pinnate Tansymustard
Descurainia richardsonii	Richardson Tanysmustard
Draba numorosa	Woods Draba
Erysimum inconspicuum	Small-flowered Wallflower
Erysimum repandum	Repand Wallflower
Isatis tinctoria	Yellow Woad
Lepidium sativum	Gardencress Pepperweed
Physaria didymocarpa	Common Twinpod
Sisymbrium altissimum	Tumblemustard
Crassulaceae	
Sedum stenopetalum	Yellow Stonecrop
Roasaceae	
Fragaria vesca	Woodland Strawberry
Fragaria virginiana	Virginia Strawberry
Geum triflorum	Prairiesmoke
Potentilla glandulosa	Gland Cinquefoil

Table 20. List of the plant species found on the winter range. (continued)

SCIENTIFIC NAME	COMMON NAME
Forbs, continued	
Potentilla gracilis	Northwest Cinquefoil
Potentilla pennsylvanica	Pennsylvania Cinquefoil
Leguminosae	
**Astragalus drummondii	Drummond Milkvetch
Astragalus microcystis	Milkvetch
Astragalus missouriensis	Missouri Milkvetch
Astragalus minor	Milkvetch
Lupinus caudatus	Spurred Lupine
Lupinus sericeus	Silky Lupine
Oxytropis lagopus	Haresfoot Loco
Oxytropis spp.	Loco
**Trifolium spp.	Clover
Geraniaceae	
Geranium viscossissimum	Sticky Geranium
Linaceae	
Linum Lewisii	Wild Blue Flax
Violaceae	
Viola nuttallii	Nuttall Violet
Viola spp.	Violet
Onagraceae	
Epilobium minutum	Small Willow-herb
Umbelliferae	
Lomatium triternatum	Nineleaf Lomatium
Lomatium spp.	Prairie Parsley
Ericaceae	
Arctostaphylos uva-ursi	Kinnikinnick
Primulaceae	
Douglasai montana	Mountain Douglasia
Solanaceae	
Hyocyamus niger	Henbane
Polemoniaceae	
Collomia linearis	Narrow Leaved Collomia
Phlox hoodii	Hoods Phlox
Phlox longifolia	Longleaf Phlox
Hydrophyllaceae	
Hydrophyllum capitatum	Waterleaf
Phacelia heterophylla	Virgate Phacelia
Phacelia linearis	Linear-leaf Phacelia
Boraginaceae	
Amsinckia menziesii	Fiddle-neck
Cryptanthe bradburiana	Miners Candle
Lappula redowskii	Western Stick Tight

Table 20. List of the plant species found on the winter range (continued)

SCIENTIFIC NAME	COMMON NAME
Forbs, continued	
Lithospermum arvense	Field Gromwell
Lithospermum ruderale	Western Gromwell
Scrophulariaceae	
Castilleja lutescens	Stiff Yellow Indian Paintbrush
Castilleja spp.	Paintbrush
Collinsia parviflora	Small-flowered Blue-eyed Mary
Orthocarpus tenuifolius	Thin-leaved Orthocarpus
Penstemon albertinus	Alberta Penstemon
Penstemon procerus	Littleleaf Penstemon
Verbascum thapsus	Flannel Mullein
Plantaginaceae	
**Plantago purshii	Wooly plantain
Compositae	
Achillea millefolium	Yarrow
Agoseris aurantica	Orange Agoseris
Agoseris neterophylla	Annual Agoseris
Antennaria rosea	Rose Pussytoes
Arnica sororia	Arnica
Artemisia dracunculus	False-tarragon Sagewort
Aster canescens	Hoary Aster
Balsamorrhiza sagittata	Arrowleaf Balsamroot
Chrysopsis villosa	Golden Aster
Cirsium undulatum	Wavyleaf Thistle
Cirsium vulgare	Bull Thistle
Crepis acuminata	Tapertip Hawksbeard
Erigeron compositus	Cutleaf Daisy
Erigeron speciosus	Oregon Fleabane
Haplopappus acaulis	Stemless Goldenweed
Hieracium albiflorum	White Hawkweed
Hieracium cynoglossoides	Houndtongue Hawkweed
Senecio canus	Wooly Groundsel
Senecio integerrimus	Lambstongue Groundsel
Senecio lugens	Senecio
Senecio spp.	Groundsel
Solidago nemoralis	Goldenrod
Taraxicum officinale	Common Dandelion
Tragopogon dubius	Common Salsify
Tragopogon pratensis	Meadow Salsify

Table 20. List of the plant species found on the winter range (continued)

SCIENTIFIC NAME	COMMON NAME
Browse	
Cupressaceae	
Juniperus communis	Common Juniper
Juniperus scopulorum	Rocky Mountain Juniper
Pinaceae	
Pinus contorta	Lodgepole Pine
Pinus ponderosa	Ponderosa Pine
Pseudotsuga menziesii	Douglas Fir
Salicaceae	
Populus tremuloides	Quaking Aspen
Populus trichocarpa	Black Cottonwood
Salix spp.	Willow
Betulaceae	
Alnus incana	Thinleaf Alder
***Betula occidentalis*	Water Birch
Rosaceae	
Amelanchier alnifolia	Western Serviceberry
Physocarpus malvaceus	Ninebark
Potentilla fruiticosa	Shrubby Cinquefoil
Prunus virginiana	Chokecherry
Rosa woodsii	Woods Rose
Aceraceae	
Acer glabrum	Rocky Mountain Maple
Cornaceae	
Cornus stolonifera	Red Dogwood
Ericaceae	
***Vaccinium membranaceum*	Thinleaved Huckleberry
Vaccinium scoparium	Low Red Huckleberry
Polemoniaceae	
Leptodactylon pungens	Granite Gilia
Caprifoliaceae	
Symphoricarpos albus	Common Snowberry
Compositae	
Artemisia frigida	Fringed Sagewort
Artemisia tridentata	Big Sagebrush
Chrysothamnus nauseosus	Rubber Rabbitbrush
Chrysothamnus viscidiflorus	Green Rabbitbrush
Tetradymia canescens	Gray Horsebrush

Table 20. List of the plant species found on the winter range (continued)

SCIENTIFIC NAME	COMMON NAME
Grasses, Grass-like Plants, Sphenopsids, Mosses and Lichens	
Equisetaceae	
Equisetum spp.	Horsetail
Gramineae	
***Agropyron smithii*	Western Wheatgrass
Agropyron spicatum	Bluebunch Wheatgrass
Bromus marginata	Big Brome
Bromus tectorum	Cheatgrass Brome
Calamagrostis rubescens	Pinegrass
***Danthonia spicata*	Poverty Oatgrass
***Danthonia unispicata*	One-spike Oatgrass
Elymus cinerius	Basin Giant Rye
Festuca idahoensis	Idaho Fescue
Festuca scabrella	Rough Fescue
Koelaria cristata	Prairie Junegrass
Melica bulbosa	Onion Grass
Phleum pratense	Timothy
Poa pratense	Kentucky Bluegrass
Poa secunda	Sandberg Bluegrass
Stipa comata	Needle and Thread
Cyperaceae	
Carex platylepis	
Carex spp.	Sedge
Juncaceae	
Juncus balticus	Wirerush
Mosses and Lichens	

*Identification and common names from Hitchcock, *et al*. (1959), Booth and Wright (1959), and Moss (1959).
**From Aderhold (MS).

Table 21. Summary of Plant Density by % Foliar Coverage at eight Transect Sites (50-1 ft^2 plots per transect)*

Species	% Modified Canopy Coverage							
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Acmi	1.45	2.55	2.85	1.70	17.45	5.65	38.90	43.8
Agsp	31.65	43.42	19.71	9.95	3.65	11.25	3.15	17.50
Alce							T	
Amal			2.80					
Arro	T	2.5	T	T			2.2	
Arabis	T	T		T		11.6	T	T
Arco		T		2.4	T	4.90	3.90	
Ardr			5.60					
Arfr	15.35	10.50	33.30	10.00			T	2.35
Arso					18.55		7.50	6.55
Artr					48.60			
Asdr	11.50			2.30		T		
Basa							20.70	34.10
Brte	T	T	4.00	6.05	2.1	15.65	3.50	5.10
<u>Capsella</u> spp.							T	
<u>Carex</u> spp.					T		1.0	
<u>Castilleja</u> spp.					T			
Casu	T	2.70		T	2.60	T		T
Cear						T	T	
Chna	1.80	2.35		13.00				3.55
Chvi (Aster)				16.50				
Chvi (Rabbitbr.)							T	
Ciun	1.10	1.10				1.15		
Coli	3.70	2.95	2.65	2.10	3.95	4.50	3.25	1.65
<u>Commelina</u> spp.		3.15	4.10	T				T
Copa		T	T		T		T	2.35
Crac	2.45	T		1.70	4.75	6.25	11.60	2.20

Table 21. Summary of Plant Density by % Foliar Coverage at eight Transect Sites (50-1 ft^2 plots per transect)* (continued)

Species	% Modified Canopy Coverage							
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Crbr	T	T		T		1.70	T	
Draba spp.					1.50		T	1.25
Erco	T	2.85		2.65	T	7.7	T	
Eriogonum spp.		1.4						
Ersp					T	6.3	T	
Feid	T	1.25		19.40	34.00	1.05	33.20	4.20
Fese	T	3.20						
Frvi							T	
Getr					T		T	
Gevi							T	
Hial		T	T				T	
Hyca							T	
Kocr	13.85	14.75		6.20	1.70	6.95	3.10	3.95
Lare						2.00	T	T
Lepu	8.15	13.40						
Lespidium spp.							T	
Lile	T	T		T				
Liru					4.00		5.70	T
Lomatium spp.			3.50	1.0				
Lotr		T			T			T
Luse	1.90	1.25		2.00	36.00	11.6	38.50	50.20
Mosses	1.00							
Oxytropis spp.				T		T		
Orte					1.3	T		T
Phhe	T							
Phho				7.80		1.30	1.00	
Phli	3.10	T	1.25	5.30	1.15	7.50	T	8.75
Pogl							T	

Table 21. Summary of Plant Density by % Foliar Coverage at eight Transect Sites (50-1 ft^2 plots per transect)* (continued)

Species	% Modified Canopy Coverage							
	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Pose	5.85	4.20		1.6	2.00	3.5	6.80	3.4
Prva			5.60					
Rowo			2.80					
Senecio spp.			T					
Sophia spp.						T	T	T
Taof							1.1	
Trdu	1.05							
Trpr		1.05		3.30	T	1.20	T	T
Viola spp.							4.65	
Zyel					T			
Misc.	7.50	6.1	3.85	2.00	6.10	18.85	11.4	3.30
Total	109.94	119.52	89.61	120.45	188.95	118.55	203.85	194.20

*Less than 1% = T.

Table 22. Ecological role of some plants on the Rock Creek winter range*

Plant	Decreaser	Increaser	Invader
Acer glabrum	x		
Achillea millefolium		x	
Agropyron smithii		x	
Agropyron spicatum	x		
Allium cernum		x	
Amelanchier alnifolia	x	x	
Amsinckia menziesii			x
Antennaria rosea		x	
Arabis microphylla		x	
Arctostaphylos uva-ursi		x	
Arenaria conjesta			x
Artemisia dracunculus			x
Artemesia frigida		x	x
Artemesia tridentata		x	
Aster canescens			x
Balsamorhiza sagittata		x	
Bromus marginatus	x		
Bromus tectorum			x
Calamagrostis rubescens		x	
Carex spp.	x		
Castilleja spp.		x	
Chrysopsis villosa		x	
Chrysothamnus nauseosus			x
Chrysothamnus viscidiflorus			x
Cirsium undulatum			x
Cirsium vulgare			x
Collinsia parviflora			x
Cornus stolonifera	x		
Crepis acuminata		x	
Danthonia spicata			x
Danthonia unispicata			x
Delphinium bicolor		x	
Elymus cinereus		x	
Equisetum spp.			x
Erigeron speciosus			x
Eriogonum spp.			x
Festuca idahoensis	x	x	
Festuca scabrella	x		
Frageria vesca			x
Frageria virginiana			x
Geranium viscossissimum	x	x	
Hieracium albiflorum	x	x	
Hieracium cynoglossoides	x	x	
Juncus balticus			x
Juniperus communis		x	
Juniperus scopulorum		x	

Table 22. Ecological role of some plants on the Rock Creek winter range* (continued)

Plant	Decreaser	Increaser	Invader
Koelaria cristata		x	
Lepidium sativa			x
Lewisia rediviva			x
Lomatium simplex	x		
Lupinus sericeus		x	
Melica bulbosa	x		
Oxytropis spp.		x	
Penstemon procerus		x	
Phacelia neterophylla			x
Phadelia linearis			x
Phlox hoodii		x	
Phlox longifolius		x	
Physocarpus malvaceus		x	
Plantago purshii			x
Poa pratense			x
Poa secunda		x	
Polygonum douglasii			x
Potentilla fruiticosa		x	
Potentilla glandulosa			x
Potentilla gracilis			x
Potentilla pennsylvanicus			x
Primus virginiana		x	
Rosa woodsii		x	
Sedum stenopetalum			x
Senecio cana			x
Senecio integerrimus	x	x	
Sisymbrium altissimum		x	x
Solidago nemoralis			x
Stipa comata		x	x
Symphoricarpus alba		x	
Taraxacum officianale			x
Tetradymia canescens			x
Tragopogon dubius			x
Tragopogon pratensis			x
Vaccinium scoparium		x	
Verbascum thapsus			x
Zygadenus elegans		x	x
Zygadenus paniculatus		x	x

*Data from lists prepared by Morris, the Soil Conservation Service, and the U. S. Forest Service on file at the Department of Range Management, University of Montana.

Table 23. Herbage production in grams from 50-4.8 ft^2 plots in five exclosures

Species	Exclosure 1		Exclosure 2		Exclosure 3		Exclosure 4		Exclosure 5	
	Total	Rank	Total	Rank	Total	Rank	Total	Rank	Total	Rank
Acmi	0.20	7			0.28	12	101.38	4	19.95	4
Agsp	168.15	2	238.08	1	218.53	1	313.29	1	41.24	3
Alce									0.35	20
Anro			0.61	19					3.29	9
Arabis spp.			2.20	14						
Arco									13.44	5
Arfr	37.70	3	57.28	3	73.77	4	22.56	6	0.97	15
Asdr					22.93	7				
Astragalus spp.			1.50	16						
Brma			1.20	17						
Brte					8.95	9	189.99	3		
Cami									1.49	14
Chvi			8.57	8						
Cium			2.10	15						
Coli	0.33	6					0.76	15	0.08	20
Copa							1.51	10	0.05	23
Crac			2.97	12					1.97	11
Crbr			12.05	5						
Draba spp.							0.09	20		
Erco			27.38	4	63.60	5			7.94	7
Feid			3.74	8	87.11	3	1.50	11	58.62	1
Fesc									41.84	2
Haac			0.49	20						
Hial					0.03	13				
Kocr	14.09	4	83.24	2	39.93	6			4.32	8
Lepu	191.25	1								
Lotr									0.59	18
Luse					87.53	2	237.61	2	13.02	6
Pecy	0.10	8	1.20	18						

Table 23. Herbage production in grams from 50-4.8 ft^2 plots in five exclosures (continued)

Species	Exclosure 1		Exclosure 2		Exclosure 3		Exclosure 4		Exclosure 5	
	Total	Rank	Total	Rank	Total	Rank	Total	Rank	Total	Rank
Phho			7.48	9						
Phli					5.08	10	28.53	5	0.74	16
Podo							0.33	18	1.74	13
Pose	2.20	5	2.45	13	9.98	8	7.05	8	0.51	19
Sedum spp.									2.01	10
Senecio spp.			9.32	7						
Sophia spp.							3.27	9		
Stco			11.39	6						
Trdr					0.71	11	0.87	14	1.79	12
Trdu			3.71	11			11.35	7		
Misc.							0.87	16 and 17	0.68	17
Total	414.02		476.96		617.93		921.18		216.63	

Table 30. Results of rumen samples collected from Rock Creek bighorn sheep*

Sex and number	♂-2700	♂-2701	♂-2702	♀-2698	♀-2699	♂-2771
Date	10/3/66	11/27/66	4/14/67	5/8/67	5/27/67	11/25/67
Nature of death	shot	shot	natural	shot	natural	shot
Total volume (cc)	40.65	23.3	83.9	58.95	33.4	39.0
Food item (% vol.)						
Pipo			0.36		0.99	
Psme			2.15	0.42	2.30	
Syal	0.74		0.24			0.10
Arfr						0.60
Artr						0.10
Unid. Browse	2.21		9.95	1.91	2.91	
Total Browse	2.95	0.77	3.70	2.33	6.20	1.80
Frvi	2.58				1.20	
Luse	5.65			0.34	0.30	0.10
Aruv				0.34	0.30	
Acmi				0.08		
Anro	2.21					
Erco		23.32		0.17		
Unid. Forbs	2.21	1.20	0.95	1.91	2.13	0.10
Total Forbs	12.65	24.52	0.95	2.84	2.85	0.60
Grasses and Grass-like Plants	84.38	75.54	95.35	94.83	92.81	97.70
Total Grasses	84.38	75.54	95.35	94.83	92.81	97.70

*Abbreviations are the first two letters of the specific and generic name - see Table 20.

Table 28. Forage utilization from 50-4.8 ft^2 plots clipped around five exclosures*, **

Species	Exclosure 1			Exclosure 2			Exclosure 3			Exclosure 4			Exclosure 5		
	Spring Weight	Util.	% Util.	Spring Weight	Util.	% Util.	Spring Weight	Util.	% Util.	Spring Weight	Util.	% Util.	Spring Weight	Util.	% Util.
Acmi		+1.22					0.68	+0.4		32.08	69.3		12.12	7.83	
Agsp	86.9	81.25	48.32	181.13	56.95	23.92	100.7	178.3	81.59	1.7	311.59	99.46	54.33	+13.09	+24.09
Anro	0.60	+0.60			0.51	0.10							6.92	+6.84	
Arfr	31.07	6.63	21.34	24.36	32.92	57.47	2.79	70.98	96.22	5.49	17.07	75.66	11.96	+10.99	
Brte				1.34	+1.34		11.42	+3.07		103.28	86.71	45.64			
Chna	2.73	+2.73								32.14	+32.14				
Chvi				1.97	6.60										
<u>Cirsium</u>				0.17	1.93										
Erco													2.78	5.16	
Feid							20.59	66.52	23.64	0	1.50		35.70	22.92	39.10
Fesc													24.39	17.45	41.70
Koer	12.59	1.50	10.65	23.01	60.23	72.36	2.41	37.52	93.96				1.71	2.61	
Lepu	91.06	100.19	52.39												
Liru				2.63	+2.63										

Table 28. Forage utilization from 50-4.8 ft^2 plots clipped around five exclosures*, ** (continued)

Species	Exclosure 1			Exclosure 2			Exclosure 3			Exclosure 4			Exclosure 5		
	Spring Weight	Util.	% Util.	Spring Weight	Util.	% Util.	Spring Weight	Util.	% Util.	Spring Weight	Util.	% Util.	Spring Weight	Util.	% Util.
Lotr													0.41	0.19	
Luse				17.53	17.53		12.61	74.92		5.62	231.99		3.54	9.48	
Mustards	0.32	+0.32					0.63	+0.63							
Oxytropis				0.14	+0.14										
Pecy	7.89	+7.79													
Phho				5.91	3.5										
Poco				0.55	+0.55										
Pose	0.00	2.20	100.00	0.81	1.64	67.94	0.13	9.85					7.24	+6.73	
Seca				0.76	8.56										
Sedum													2.96	+0.95	
Trdu							0.79	+0.79							
Trpr				1.42	+1.42					0.52	0.35				
Misc.				0.24	+0.24		0.53	+0.53		11.33	+11.33		6.50	+6.50	
Total	234.38	179.64	43.39	264.63	212.33	44.5	153.28	464.65	75.20	192.16	729.02	79.14	175.33	17.45	41.70

Table 28. Forage utilization from 50-4.8 ft^2 plots clipped around five exclosures*, ** (continued)

Species	Exclosure 1			Exclosure 2			Exclosure 3			Exclosure 4			Exclosure 5		
	Spring Weight	Util.	% Util.	Spring Weight	Util.	% Util.	Spring Weight	Util.	% Util.	Spring Weight	Util.	% Util.	Spring Weight	Util.	% Util.
Total (4 Grasses) ***			46.0			37.42			81.59			99.47			0

*Weight in grams (x2 = pounds per acre)
**% given for five most abundant plants except annual forbs.
***Agsp, Kocr, Feid, Pose.

Table 32. Results of rumen samples collected from Rock Creek mule deer*

Sex and number	♀-2772	♀-2773	♀-2774	♀-2775	♂-2777	♂-2776
Date	11/5/67	11/11/67	11/18/67	11/18/67	1/13/68	1/14/68
Nature of death	shot	shot	shot	shot	shot	shot
Total volume (cc)	67.8	64.0	34.5	20.2	33.9	15.3
Food item (% vol.)						
Jusc					4.7	40.5
Pipo				0.5		
Psme	3.7	27.7	3.8	13.9	30.4	3.9
Ribes spp.						
Amal					0.3	
Rowo	1.3	0.3				
Spbe					4.1	
Acgl					0.9	
Cost	10.6					37.3
Syal			5.5	13.9		6.5
Arfr	2.8	0.3	2.9			
Artr			10.1	5.9		
Chna						
Unid. Browse	0.6		4.3	34.2	17.7	17.6
Total Browse	19.0	28.3	26.6		58.1	100.0
Eriogonum spp					1.2	
Arco						
Anemone spp						
Cruciferae	1.2					
Frvi	8.4	13.4			13.3	
Getr						
Pogr	0.1					
Luca	2.4					
Luse	7.8	13.4	1.4			

Table 32. Results of rumen samples collected from Rock Creek mule deer (continued)

Sex and number	♀-2867	♀-2868	♀-2869	♂-2864	♀-2865	♀-2866
Date	2/25/68	2/25/68	2/25/68	3/27/68	4/27/68	4/27/68
Manner of death	shot	shot	shot	shot	shot	shot
Total volume (cc)	39.7	55.4	67.0	41.8	79.6	72.0
Food item (% vol.)						
Jusc	0.5			3.3		
Pipo		32.5	0.3			
Psme	0.3	9.0		0.4		1.1
Ribes spp.						0.1
Amal						
Rowo						
Spbe						
Acgl						
Cost						
Syal						0.1
Arfr	1.3		7.5			
Artr		5.7	2.1		0.1	12.5
Chna						
Unid. Browse	0.2	24.5	9.1	2.2	0.5	
Total Browse	3.1	71.7	19.0	5.9	0.6	13.8
Eriogonum spp.					0.1	
Arco	11.6					
Anemone spp.						
Cruciferae						
Frvi					0.1	0.3
Getr		1.1	1.2			
Pogr						
Luca					0.9	1.1
Luse			3.7			1.1

Table 32. Results of rumen samples collected from Rock Creek mule deer (continued)

Sex and number	♀-2772	♀-2773	♀-2774	♀-2775	♂-2777	♂-2776
Date	11/5/67	11/11/67	11/18/67	11/18/67	1/13/68	1/14/68
Nature of death	shot	shot	shot	shot	shot	shot
Total volume (cc)	67.8	64.0	34.5	20.2	33.9	15.3
Food item (% vol.)						
Oxytropis spp.						
Aruv	0.1	1.1	0.3	1.0		
Pecy	0.4					
Phli	1.8	0.6				
Acmi	0.3	0.6				
Anro						
Arso						
Erco		1.7				
Taol						
Trpr						
Unid. Forbs	63.4	40.0	32.2			
Total Forbs	81	63.5	33.9	1.0	14.5	
Grasses and grass-like plants		8.3	39.4	59.4	2.1	
Lichens					25.3	
Total Grasses and Lichens		8.3	39.4	59.4	27.4	
Misc.				5.4		

* Abbreviations are the first two letters of the specific and generid name - see Table 20.

Table 32. Results of rumen samples collected from Rock Creek mule deer (continued)

Sex and number	♂-~~3867~~ 2867	♀-2868	♀-2869	♂-2864	♀-2865	♀-2866
Date	2/25/68	2/25/68	2/25/68	3/27/68	4/27/68	4/27/68
Manner of death	shot	shot	shot	shot	shot	shot
Total volume (cc)	39.7	55.4	67.0	41.8	79.6	72.0
Food item (% vol.)						
Oxytropis spp.		0.2	3.4			
Aruv				1.4	0.4	0.1
Pecy						
Phli						
Acmi					0.4	0.4
Anro	41.3	6.3	47.5	8.6		
Arso						1.4
Erco			1.8	0.4	0.4	0.8
Taol					1.5	0.3
Trpr		0.4				
Unid. Forbs	39.6	19.7	22.6	29.0	1.4	13.9
Total Forbs	92.5	27.7	80.2	39.4	5.2	18.3
Grasses and Grass-like Plants	4.5	0.4	0.9	54.6	94.2	66.7
Lichens						
Total Grasses and Lichens	4.5	0.4	0.9	54.6	94.2	66.7
Misc.		0.4				

* Abbreviations are the first two letters of the specific and generic name - see Table 20.

APPENDIX F

Table 35. Autopsy data and live measurements from National Bison Range bighorn sheep and Wildhorse Island[1/]

Number	Sex	Date	Age	Circumstance of death	Weight (lbs) Live	Hog D. Live	Hog Dressed	Carc Live	Carcass	Carc Hog	Meas.[2/] TL
5095		5/10/58	7	Shot in neck	201			.527	106		1645
4949		6/28/58	6	Shot behind shoulder	260.5	.741	193	.550	143.5	.743	1710
5126		7/26/58	25 mo	Shot in neck	217.5	.726	158	.574	125	.791	1670
5212		8/25/58	6-7	Shot in neck	302	.735	222	.566	171	.770	1830
5116		9/18/58	6-7	Shot in eye	291	.693	201.5	.572	166.5	.826	1820
5129		10/17/58	3-4	Shot in head	257	.716	184	.549	141	.766	1680
5188		11/26/58	5	Shot in neck	275	.855	235	.618	170	.724	1890
5352		12/19/58	3	Shot in lungs	197	.761	150	.534	115	.766	1720
5353		1/24/59	3-4	Shot in neck	212	.726	154	.542	115	.747	1700
5728		2/21/59	4	Shot in neck	238	.748	178	.559	133	.748	1860
6272		3/20/59	6	Shot	195	.744	145				1730
5729		4/17/59	4	Shot in shoulder	230	.696	160	.522	120	.750	1715
WHI		5/29/59	Adult	Not shot - broken neck	127		92		75.5		1455
NBR-1		3/ 6/68	3 3/4	Live	142						56
NBR-4		3/ 6/68	3 3/4	Live	105						63
NBR-5		3/ 6/68	2 3/4	Live	120						63
NBR-7		3/ 6/68	Adult	Live	132						64
NBR-10		3/ 6/68	7 3/4	Live	130						62 1/2
NBR-12		3/ 6/68	5 3/4	Live	117						60 1/2
NBR-13		3/ 6/68	5 3/4	Live							58 3/4
NBR-14		3/ 6/68	6 3/4	Live	104						59 1/2
NBR-15		3/ 6/68	6 3/4	Live	137						62
NBR-16		3/ 6/68	1 3/4	Live	110						61

Table 35. Autopsy data and live measurements from National Bison Range bighorn sheep and Wildhorse Island[1] (continued)

Number	Sex	Date	Age	Circumstances of death							Meas.[2]
					Live	Hog D. Live	Hog Dressed	Carc Live	Carcass	Carc Hog	TL
NBR-17		3/ 6/68	1 3/4	Live	98						56 1/2
NBR-11		3/ 6/68	2 3/4	Live	131						55 1/2
NBR-9		3/ 6/68	2 3/4	Live	127						65
NBR-8		3/ 6/68	9 3/4	Live	201						65 1/2
NBR-6		3/ 6/68	2 3/4	Live	130						65 1/2
NBR-2		3/ 6/68	3 3/4	Live	175						66 1/2
NBR-3		3/ 6/68	6 3/4	Live	187						72

Table 35. Autopsy data and live measurements from National Bison Range bighorn sheep and Wildhorse Island[1] (continued)

	Measurements[2]										
Number	T	HF	E	Girth	Neck Circ	Shoulder Height	Body Temp °F [3]	Horn Length	Horn Spread	Horn Basal Circ	Both Testes
5095	125	440	115	1210	502	1180					196.5
4949	135	432	110	1195	519	1075					283
5126	150	460	118	1150	495	1100					149
5212	101	460	120	1245	578	1114					129
5116	112	474	119	1285	610	1010					318
5129	82	445	110	1320	598	1083					413
5188	125	475	125	1255	680	1225					447.5
5352	110	456	125	1240	530	1100					426
5353	109	480	120	1190	550	1125					300
5728	137	462	126	1124	550	1155					222
6272	110	457	114	1178	560	1100					254
5729	151	458	117	1260	560	1090					211.8
WHI		409	110	918	332	930					
NBR-1	3 1/2	15 1/4	4 1/2	43	20-14		100.4				
NBR-4	4 3/4	15 1/4	4 1/2	38 1/4	21 1/2-13		101.0				
NBR-5	4 1/2	16	4 1/2	38 1/2	19 1/2-13 3/4		100.6	9	13 3/4	6	
NBR-7	5	16 1/4	4 1/2	42	23-14 1/2		103.0	11	16	5 1/4	
NBR-10	4 3/4	16	4 1/2	40	18 1/2-15		98.0	11 1/2	16 3/4	6 1/4	
NBR-12	3 3/4	15 1/2	4 1/2	38	18 1/2-13		101.4	12	15 1/8	6	
NBR-13	5	16	4 1/2	41 1/2	19 1/2-13 3/4		102.0	10	13 1/2	5 3/4	
NBR-14	4 3/4	15 1/4	4 1/4	36 1/2	15-12		103.4	9 5/8	11 1/2	5 1/2	
NBR-15	4 1/2	16	4 1/2	38 1/2	18-14 1/4		101.4	11	14 7/8	6 1/4	
NBR-16	4	16 1/2	4 1/4	37 1/2	18 1/2-14		101.0	14 1/2	18 1/2	9 1/8	
NBR-17	5 1/2	16 3/8	4 1/2	38	17 1/2-13 1/2		103.0	15 1/2	16 3/8	9 1/2	
NBR-11	5 1/2	17 3/4	4 1/2	38 1/2	20-15 1/2		102.0	17 1/2	19	10 1/4	
NBR-9	5	17	4 1/2	38 1/2	22-14 1/4		100.0	18 1/4	20 1/4	11	

Table 35. Autopsy data and live measurements from National Bison Range bighorn sheep and Wildhorse Island[1] (continued)

	Measurements[2]										
Number	T	HF	E	Girth	Neck Circ	Shoulder Height	Body Temp °F. [3]	Horn Length	Horn Spread	Horn Basal Circ	Both Testes
NBR-8	4 3/4	18	4 1/4	45 1/2	26 1/2-19		103.0	32 1/8	19	13 5/8	
NBR-6	4 3/4	16 1/2	5	39 1/2	21 1/2-15 1/2		101.2	17 1/2	19 1/2	10 1/4	
NBR-2	4 3/4	17	4 3/4	43	21-17 1/2		102.3	22 1/2	19	12	
NBR-3	5	17 1/2	4 1/2	44	26 1/2-19		102.2	30 1/2	19 1/2	14 1/4	

Table 35. Autopsy data and live measurements from National Bison Range bighorn sheep and Wildhorse Island[1] (continued)

	Gland and Organ Weights (gm)										Parasites and Comments
							Heart		Kidneys		
Number	Thyroid	Adrenals	Thymus	Spleen	Lungs	Liver	Fat	No Fat	Fat	No Fat	
5095	2.9	3.2	2.9	111.5		1059	700	659		97	1 bladderworm in viscera, 430+ nematodes 130 nematodirus, no lungworm, no ectoparasites, beginning to shed at neck and side
4949	6.0	3.2	1.1	119		1427	808.5	731.5	276	126.5	2 bladderworms in liver no abnormal nematodes
5126	7.5	2.3	7.1	95		1142	560	502	227.5	95.5	bladderworms in liver 206 intestinal nematodes
5212	5.5	3.4		135		1073	820	680	300.5	119.5	intestinal nematodes approx. 2410, abomasal nematodes approx. 642
5116	4.6	3.2		116		1011	720	622	246	95	bladderworms: 1-liver, 1-mesentary, 1 *oestrus ovis* in lung and 1 in trachea-both 1st instar 3115 instestinal nematodes, 0 abomasal nematodes
5129	4.19	2.1		112		1090	796	701	264.3	87.5	2 bladderworms in mesentery, 3800 intestinal nematodes, 175 abomasal nematodes
5188		3.1		145		1044	855	772	239	99	1 bladderworm near abomasum - no lungworm or botts, 2♀ *Dermacentor albipictus*

Table 35. Autopsy data and live measurements from National Bison Range bighorn sheep and Wildhorse Island[1] (continued)

	Gland and Organ Weights (gm)										Parasites and Comments
							Heart		Kidneys (ave)		
Number	Thyroid	Adrenals	Thymus	Spleen	Lungs	Liver	Fat	No Fat	Fat	No Fat	
5352	3.1	2.4		117		741	619	564	109.5	79.5	1 bladder worm in liver, moderate lungworm, 2 *Dermacentor albipictus* 2 nymphs, 1540 intestinal nematodes, 180 abomasal nematodes
5353	4.0	2.1		103		792	633	610	86.25	75.5	1580 intestinal nematodes, 70 abomasal nematodes
5728	4.1	3.1	0.7	114.5		919.8	904	852	108.5	83.3	2700 intestinal nematodes, 530 abomasal nematodes
6272		1.9		123.5		761.2	569.6	541.5	83.8	73.5	2♀, 1♂ *Dermacentor andersoni*, 3 bladderworms, 5020 intestinal nematodes, 420 abomasal nematodes
5729	7.2	2.7		139.2		1240.4	701.7	651.5	128.6	99.1	bladderworms
WHI				76.5		1138.9	555	452.4	258 123.2[3]	202.2 30.2	weight of udder-5116

[1]Data from 1958-59 collected by Dr. P. L. Wright, Department of Zoology, University of Montana.
[2]Except where noted, 1958-59 measurements in gm and cm; 1968 measurements in gm and inches.
[3]Due to the variation of the weights of each kidney, both measurements are included.

Table 37. Results of Rock Creek bighorn sheep autopsies*

No Sex	Age	Date	Circumstance of Death	Weight Total	Weight Carcass	Fetus No.	G-I Tract (ft and in) Small Int	Large Int	Caecum
1 ♀	4 3/4	5/ 8/67	Illegally shot 5/7/67	69	34	1 mummy			
2 ♀	3 3/4	5/27/67	Natural - dead @ 2 weeks	75.5		0			
3 ♂	2 1/2	10/ 3/66	shot				82'6"	23'	
4 ♂	2 1/2	11/27/66	shot	@120	67		67'	25'4"	1'2"
5 ♂	8 3/4	4/14/67	Natural injured rt front foot	129	59				

Table 37. (continued)

	Body Measurements (in.)							
No	TL -	T -	HF -	E	Chest Girth	Neck at: smallest	largest	shoulder height
1	56	2 3/4	?	3 3/4	36	12	16	28 1/2
2	51	?	14	?		13 1/4	15 3/4	
3								
4								
5	63	3 1/2	15 3/4	4 1/8	40	15		

Table 37. Results of Rock Creek bighorn sheep autopsies* (continued)

No	Liver	Spleen	Heart Fat + -	Kidney Fat** + -	Adrenal**	Lungs	Testes	Kidney Fat Index	Comments
1	639.7		279.8	72.7-66.6	5.5	507.4		8.4	A few ticks, skin wt = 8 lbs
2			334-334	76.8-76.8	5.5			0	Atrial portion of heart and adjacent body wall, bloodshot
3			424.5-361.2	117.2-86.8	6.3		71.2	25.9	Node on adrenal
4			-454.5	157.6-87.4			136.0	44.5	
5	748.5	95	-366.8	93.38-93.38	6.4	985.0		0	Skin wt = 12.5 Head wt = 21.5

**Average of 2.

Table 38. Nutrient requirements of domestic sheep and deer in % total ration (based on air-dry feed containing 90% dry matter)*

Animal	Feed #/animal	% TDN	% Protein	% DP*	% Ca	% P	mg Carotene	D. E. in Cal	% Mg	K	Mn	F
100 lb ewe first 15 weeks of gestation, non-lactating	2.6	50	8	4.4	.27	.21	0.7	830 cal/lb forage	0.06			not over 30 ppm
100 lb ewe, last 6 weeks of gestation	3.8	52	8.4	4.6	.24	.18	1.5		0.06			
100 lb lamb and yearling males	3.7	57	8.6	4.7	.18	.16	0.8		0.06			
130 lb pregnant sheep under range conditions	3.5	40		4.4		.17						
male whitetailed fawns			13-16[1] 20.2[2]									
whitetailed deer	3-4				.09	.25+[1]						
deer[3]			7 min 5 crit 7-8[4]									

*Unless otherwise noted, figures are from NAS-NAC (1964)
[1]/French (1956)
[2]/Ullrey, et al. (1967)
[3]/Einarsen (1946)
[4]/Hill (1956)

Table 39. Results of chemical analyses of Rock Creek forage plants

No.	Desc Sample	Date	Location	% Mg	% Nitr	% Protein	% Ether Extract	% Ash	% NFE	% Crude Fibre	% P	% Ca	ug/g mg/lb Carotene	% K	% Mn	% Fluoride
1	Agsp	1/13	Flat Gulch Ridge	.050	less than .02	4.4	2.5	4.8	46.34	40.9	.09	.15	.68	.090	.0019	
2	Agsp	3/9	Face Brewer's Ridge	.062	"	3.6	1.2	9.4	43.31	39.8	.09	.09	2.5	.10	.0038	
3	Agsp	3/16	Fe sc patch Bighorn Campgrd	.034	"	3.7	4.0	5.6	45.9	38.8	.03	.13	1.8	.050	.0021	
4	Agsp	3/16	Jimmy Leaf	.065	"	3.6	2.9	7.4	44.74	39.3	.03	.16	1.8	.068	.0023	
5	Fese	3/16	Bighorn Campgrd	.064	"	4.8	3.3	9.5	46.17	34.5	.07	.08	1.4	.12	.011	
6	Agsp	3/9	1 mi back on Sheep Gulch Rd	.038	"	4.4	2.7	4.6	47.03	40.03	.06	.09	.68	.10	.0043	
7	Feid	3/16	Fese patch Bighorn Campgrd	.065	"	6.8	3.7	10.6	52.67	31.0	.08	.18	1.6	.10	.0106	
8	Feid	3/16	W. face Brewer's Ridge	.091	"	5.5	2.4	16.6	42.46	31.1	.09	.13	1.4	.22	.0125	
9	Agsp	3/15	S. face b/w Mill and Windlass	.026	"	3.8	2.8	8.4	46.1	37.5	.06	.12	.68	.11	.0205	

Table 39. Results of chemical analyses of Rock Creek forage plants (continued)

No.	Desc Sample	Date	Location	% Mg	% Nitr	% Protein	% Ether Extract	% Ash	% NFE	% Crude Fibre	% P	% Ca	ug/g mg/lb Carotene	% K	% Mn	% Fluoride
10	Feid	3/9	1 mi back on sheep creek ridge	.065	"	6.4	3.7	11.7	46.1	30.2	.11	.10	1.4	.20	.0178	
11	Feid	3/15	b/w Windlass and Miss x fr. saddle	.043	"	6.0	3.8	10.5	46.33	31.1	.10	.16	1.8	.16	.0096	
12	Agsp	3/16	1 mi N of ex 4 on rocky sl	.041	"	3.8	2.9	5.8	48.81	37.7	.05	.14	.68	.066	.0127	
13	Ex. 1 Agsp	4/5		.038	"	4.7	2.2	8.9	44.57	38.9	.05	.09	.45	.10	.0035	
14	Ex. 2	4/6		.037	"	4.0	2.4	9.3	45.33	37.9	.04	.22	.68	.090	.0039	
15	Ex. 3	4/5		.015	"	5.8	2.6	6.1	43.25	40.5	.07	.10	1.4	.16	.0028	
16	Ex. 4	4/7		.043	"	4.1	2.8	8.9	42.77	40.1	.08	.11	1.1	.11	.0004	
17	Ex. 5	4/7		.026	"	5.0	2.3	8.9	40.88	41.5	.08	.08	1.1	.13	.0038	
18	Agsp	7/1/67	coll. fr. all 5 ex. and all portions	.056	.02	5.4	3.3	11.1	39.2	32.0	.10	.29	7.7	.83	.0046	.0004

Table 41. Chemical composition of some browse and grasses important as game forage in Montana (for months of winter range occupancy)

Plant	Date Collected	Source	% Crude Protein	% Crude Fibre	% Ether Extract	% Ca	% P	% Ash	% Caro-tene	% NFE
<u>Browse</u>										
Serviceberry		Evaro, *<u>1</u>/								
<u>Amelanchier alnifolia</u>	Winter	Montana	5.5	24.7	4.1	1.94	.12			57.7
Big Sage	January	Cache de Poudre	8.5	18.2		.62	.21	3.4		57.5
<u>Artemesia tridentata</u>	April	Colorado <u>2</u>/	11.4	18.0		.77	.25	3.6		53.8
Mt. mahogany	January	" <u>2</u>/	7.8	32.6		.66	.11	2.2		53.8
<u>Cercocarpus montanus</u>	April		8.6	33.5		.74	.15	2.2		51.3
Bitterbrush	January	" <u>2</u>/	8.0	26.5		.56	.11	2.1		58.2
<u>Purshia tridentata</u>	April		8.1	27.8		.57	.13	2.0		56.8
Snowbrush*	Dec-Mar	Rattlesnake								
<u>Ceanothus velutinus</u>		Montana <u>4</u>/	8.1	17.3	6.2	.92	.08	3.1	8.1	
Chokecherry	"	"								
<u>Prunus virginiana</u>			7.4	28.6	2.1	1.55	.11	3.6	2.7	
mean % composition, browse			8.2	25.2	4.1	.93	.14	2.8	5.4	55.6
<u>Grasses</u>										
		Blackfoot,								
Bunchgrass (spp.)	Fall	Montana <u>1</u>/	4.0	36.4	3.64	.47	.41		1.33	44.5
		Sun River, <u>1</u>/								
Bunchgrass (spp.)	Spring	Gallatin, Montana	3.1	37.6	2.60	.43	.04			45.3
Bluebunch Wheatgrass		Bitterroot,								
<u>Agropyron spicatum</u>		Montana <u>3</u>/	3.8			.22	.08		1.4	
Rough fescue		Bitterroot,								
<u>Festuca scabrella</u>		Montana <u>3</u>/	4.3				.04			
mean % composition, grass			3.8	37.0	3.12	.37	.14		1.37	44.9

<u>1</u>/ Morris (unpub.)
<u>2</u>/ Dietz, <u>et al</u>. (1962)
<u>3</u>/ Graham (1968, <u>pers</u>. <u>comm</u>.)
<u>4</u>/ Knoche (1968)
* Leaves and current stems.

Table 42. Skeletal measurements taken of sheep from Rock Creek, the National Bison Range, and Wildhorse Island (all measurements in mm)

Locale	Museum Number*	Sex	Age	Basilar Length	Post dental Length	Zygo-matic Width	Jaw Length
Rock Creek							
	68-13	? (lamb)	8 mo			88.3	110.3
	12615	♀	26 mo	205.5	59.7	104.6	144.7
	68-3	♀	30 mo	220.6	68.0	108.1	153.1
	4129	♀	3	244.1	79.0	119.1	164.3
	66811	♀	3 1/2	238.9	81.2	113.7	163.5
	68-5	♀	3 1/2	238.1	77.0	114.9	
	12620	♀	3 1/2	235.8	80.3	116.8	
	68-12	♀	4	242.9	82.0	118.0	
	12614	♀	4	237.9	79.1	115.3	153.7
	68-4	♀	4			115.6	
	12621	♀	4 1/2		82.8	115.5	
	12616	♀	4-5	236.5	76.7	116.9	153.9
	68-1	♀	5		84.6	117.0	167.5
	68-2	♀	5	238.7	80.9	111.7	164.1
	7A687	♀	5 1/2		78.6	117.4	
	00689	♀	6	239.6	76.1	118.4	162.9
	68-13	♂	25 mo		64.1	103.4	136.8
	12617	♂	33 mo		74.5	114.7	176.1
	12618	♂	34 mo		78.0	116.9	
	4130	♂	4	262.0	85.0	132.1	176.1
	68-8	♂	4 1/2				165.5
	12619	♂	5		90.5	125.8	
	68-13	♂	8 3/4	295.3	97.3	133.2	190
Wildhorse Island							
	7929	♀	23 mo	208.2		103.2	145.5
	5833	♀	30 mo		80.1	113.1	
	4103	♀	2 1/2	232.0	78.0	113.8	162.2
	4480	♀	4				194.2
	7913	♀	4		89.5	117.6	172.3
	7911	♀	5		83.4	112.5	
	7910	♀	6	245.0			172.4
	7919	♀	8		92.5	121.2	
	4007	♀	8 1/2	255.0	87.5	115.3	167.7
	6307	♂	5 mo	174.6		95.5	
	7908	♂	1			106.9	
	7923	♂	18 mo	241.6	90.3	118.5	
	8458	♂	19 mo		98.2	109.3	144.2
	7925	♂	23 mo			107.6	150.8
	4021	♂	28 mo				172.8
	7941	♂	5		99.0	127.3	

Table 42. Skeletal measurements taken of sheep from Rock Creek, the National Bison Range, and Wildhorse Island (all measurements in mm) (continued)

Locale	Museum Number*	Sex	Age	Basilar Length	Post-dental Length	Zygomatic Width	Jaw Length
Wildhorse Island							
	7926	♂	5				197.7
	7907	♂	6				192.0
	7932	♂	6-7	282.5	105.7	137.3	194.0
	7905	♂	7-8	285.6	101.1	133.6	189.4
	5193	♂	8		107.4	138.3	195.1
	7904	♂	8	287.3	107.6	134.2	190.1
	7931	♂	8	286.0	103.2	133.8	
	7918	♂	9		111.5	147.4	196.8
	7902	♂	9	279.2	104.4	136.0	187.3
National Bison Range	5126	♂	25 mo	270.5	91.0	130.6	186.4
	5352	♂	3	279.5	99.0	132.2	188.7
	3829	♂	4	278.2	96.8	134.2	186.8
	5129	♂	4	278.4	111.0	138.9	185.4
	5728	♂	4	301.9	109.8	138.2	204.8
	5729	♂	4	282.3	99.8	136.8	189.4
	8457	♂	4		91.1	130.6	
	5076	♂	4 1/2	293.1	103.3	138.8	195.9
	5188	♂	5	287.5	107.1	142.4	197.4
	4949	♂	6	282.7	99.9	137.7	199.7
	5212	♂	6				196.5
	8464	♂	6				195.0
	5116	♂	6-7	288.0	101.7	142.5	193.8

*Some of the Rock Creek entries which have not been catalogued in the University of Montana museum have my numbers which will eventually appear in the catalogue with the museum number.

APPENDIX G

Table 1. Land ownership on Rock Creek winter range (by species of game)*

Species	Ownership												
	National Forest			BLM	State	Private							Total
Deer	Lolo	Deer Lodge	Sub Tot			Boomer	Luthje	Neal	Gillis	Parfitt	Gromley		
Deer		560	560	288	272	432		1448	72	80	240	2272	3392
Deer and elk	368		368	98		128	80					208	656
Deer and sheep	208	256	464	48	144	112		150	15	48	10	335	1088
Moose	48		48	48		16		16	32			64	160
Total (Unduplicated)	416	560	976	336	272							2512	4096
% (of 4096)	10.15	13.67	23.82	8.2	6.64							61.33	

*in acres.

Table 43. Hunting regulations affecting the Rock Creek bighorn sheep (from Aderhold, MS)

Year	Limit	Season	No. Days	Success
1872	1st season - no limit	Aug 15- Feb 1	169	
1873-1887	none	July 15- Feb 1	200	
1885	none; law prohibiting sale of hides out of state			
1887-1889	law prohibiting sale of game meat	Sept 15- Jan 1	107	
1891-1892	none	Sept 15- Jan 15	122	
1893-1896	none	Aug 15- Dec 15	122	
1895	none; first game wardens	"	"	
1897	first bag limits	"	"	
1901-1903	6 - either sex	"	"	
1903-1905	(bighorn sheep season closed)			
1905-1906	1st hunting license sold 1 - either sex	Sept 1- Dec 31	122	
1907-1908	1 - either sex	Sept 1- Nov 30	91	
1909-1912	1 - either sex	Oct 1- Nov 30	61	
1913-1914	1, adult ram	"		
1915-1953	bighorn sheep closed to hunting			
1954-	Rock Creek opened to permit hunting - 5 rams, 3/4 curl	Sept 15- Nov 15	62	7
1956-1957	closed			
1958	5 rams, 3/4 curl	Oct 19- Nov 30	42	4
1959	closed			
1960	4 rams, 3/4 curl	Oct 16- Nov 20	35	4
1961	5 rams, 5 either sex adults	Oct 15- Nov 19	35	10
1962	25 either sex adults	Oct 21- Nov 25	35	19
1963	10 either sex adults	Sept 15- Nov 24	69	10
1964	5 rams, 3/4 curl	Sept 19- Nov 22	64	3
1965	5 rams, 3/4 curl	Oct 24- Nov 28	35	3
1966	5 either sex adults	Sept 24- Nov 27	65	3
1967	5 either sex adults	Sept 23- Nov 26	63	1
1968	closed			

APPENDIX H

Details of the Proposed Sale of the Boomer-Brewer Ranch

An indication of the skyrocketing value of land in the Rock Creek area may be demonstrated by the property speculation which is occurring for the Boomer-Brewer ranch lands. This 1,399 acre site occupies an extremely important portion of the winter range as can be seen in Fig. 40 and from the discussion of sheep movements presented Part III: Behavior. About 20% of the sheep population utilize this site. In 1965 Mr. Boomer, a rancher from Hall, Montana, purchased this property from its prior owner, Mrs. Andresen, for about $33,000. Nearly 600 domestic sheep badly overgrazed the property in 1965 and the forage has been overutilized ever since. My exclosure ~~exclusive~~ site 4 showed over 99% utilization by weight of palatable grasses. In spite of the depreciation of the range for livestock (and in part because of it) Mr. Boomer and his lessee Mr. Chester Brewer plan to sell the ranch at this time. Currently he is attempting to sell two tracts of 28 and 54 acres respectively for about $30,000. These are both poor sites except for the river access. He believes that the 54-acre piece and two other 1-acre sites are nearly sold--the large one to a gentleman from California for recreational purposes.